Automatic Train Control

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AUTOMATIC TRAIN CONTROL

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NOTE.—This book is made up of separate parts, or sections, as indicated by their titles, and the page numbers of each usually begin with 1. In this list of contents the titles of the parts are given in the order in which they appear in the book, and under each title is a full synopsis of the subjects treated.

AUTOMATIC TRAIN CONTROL

AUTOMATIC TRAIN CONTROL

Serial 2508 Edition 1

TYPES OF AUTOMATIC TRAIN CONTROL

INTRODUCTION

1. Purpose of Automatic Train Control.—The purpose of automatic train control is to control automatically the movement of a train in the event of inability or failure of the engineer to obey the signals. The control of the train is left entirely with the engineer as long as he obeys the requirements of the signal indications; when he fails to do so, the automatic train control operates and brings the train to a stop. With train control, it is therefore possible to increase the safe running speed of trains and also to decrease the clearance between trains.

2. Electric and Pneumatic Equipment.—The automatic train-control apparatus comprises two sets of equipment, the electric and the pneumatic. Under certain conditions the action of the electrical apparatus brings about the operation of the pneumatic apparatus, which then applies the brakes.

3. Explanation of Types.—Automatic train control falls into two general types; namely, continuous and intermittent. The distinction between these two types of control can be understood from the following: Assume that a train moving in the direction of the arrow, Fig. 1, approaches a caution signal; this implies that another train is occupying block 2. As the train passes the caution signal, the cab signal changes from clear to caution. The engineer is now required to take a certain action, known as acknowledging; should he fail to acknowledge, the

brakes are applied automatically by the train-control apparatus. It is difficult to define briefly the exact meaning of the term acknowledging; the meaning varies somewhat with the different equipments. In a broad sense the term refers to the act of preventing the train-control equipment from cutting in, this act being performed by the acknowledging switch or lever.

To illustrate, it is assumed that the engineer takes the required action immediately after entering block 1, and is therefore proceeding at reduced speed. In the meantime should the train ahead be running at such a speed that it leaves block 3 before the other train enters block 2, the cab signal will at once change to clear and the latter train can immediately resume normal running speed. This is termed continuous train control, because the

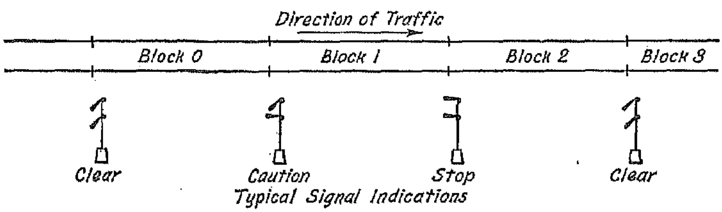


FIG. 1

engineer is continually informed of track conditions in the blocks ahead.

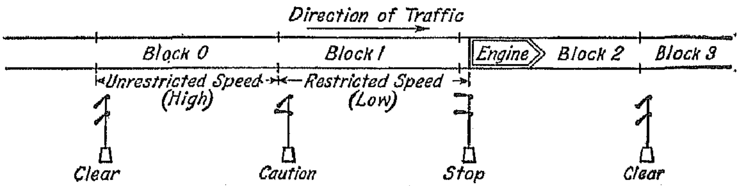
4. Cab lights cannot be used with intermittent train control. At the moment the train passes a caution signal, the engineer is required to acknowledge it; he then usually applies the brakes and reduces the speed enough to permit a stop at the home signal. Even should block 2 now clear up, the engineer has no means of knowing this fact until he approaches close enough to observe the signal. Therefore, the train control is said to be intermittent because, after passing the caution signal, the engineer has no indication of change in track conditions in the blocks ahead until he nears the home signal. In other words, he receives no indication of a change in track conditions while running between wayside signals.

5. Summary.—The foregoing can be summarized by saying that a continuous train control is one in which the engineer

is immediately notified by his cab signal of any change in track conditions ahead. With intermittent train control the engineer is only informed of track conditions intermittently; that is, when approaching the wayside signals. The advantage of continuous train control then, is that, when running in a restricted block, the engineer is immediately notified when the signals clear up; and normal running speed can be resumed.

DIVISIONS OF CONTINUOUS TRAIN CONTROL

6. **Classification.**—There are two divisions of continuous train control; namely, speed control and automatic stop. Speed control may be divided into two classes; the two-speed control and the three-speed control, these equipments always being sup-



Speed-Signal Relation. Two-Speed System

FIG. 2

plied with axle governors. An automatic stop imposes no speed limit; it furnishes a continuous cab indication. Each change of cab indication to a more restrictive condition requires an acknowledgement on the part of the engineer, otherwise the train will be automatically stopped.

7. **Two-Speed Type.**—With the two-speed type of train control, the train can move at unrestricted speed in clear blocks; in caution and occupied blocks, the speed is gradually reduced below the low-speed limit, usually 20 miles per hour; this speed cannot be exceeded until a "clear" indication is received in the cab. The relation of the speeds with respect to the block signals is shown in Fig. 2.

8. **Three-Speed Type.**—With the three-speed type of train control, the train can move at an unrestricted speed in clear blocks, at a medium speed between a caution signal and the

braking point, and at a low speed between the braking point and a train in the block ahead. The foregoing is illustrated in Fig. 3. The three-speed system permits a higher speed between the caution signal and the braking point than does the two-speed system, and hence results in greater speed in train operation.

9. Automatic Stop With Continuous Cab Indication (Code System).—The two- and three-speed systems of continuous train control limit the speed of trains in caution and occupied blocks; the automatic stop with continuous cab indication stops

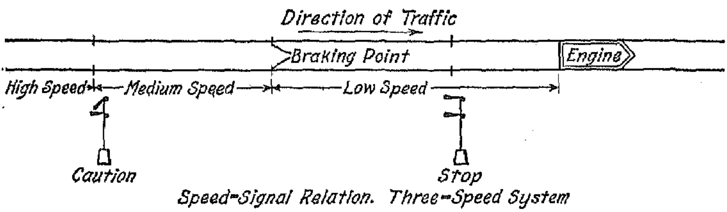


FIG. 3

the train at signals other than clear unless the engineer acknowledges and thus prevents the device from operating. Under this condition, the responsibility for the speed of the train in caution and occupied blocks is left entirely to the engineer. The continuous cab indication keeps the engineer always informed of track conditions ahead and he can therefore govern the speed accordingly. This system of train control is commonly known as the code system.

INTERMITTENT TRAIN CONTROL

10. There are no divisions of intermittent train control. This type of train control is similar to the automatic stop with continuous cab indication, except that there is no system of lights to give a continuous cab indication. Cab lights cannot be used with this type of control; instead, an audible signal is given when passing restrictive signals that have been acknowledged.

SUMMARY

11. The foregoing may be briefly summarized in the following manner:

- Automatic Train Control
  - Continuous
    - Speed Control
      - Two-speed
      - Three-speed
    - Automatic Stop (Code System)
  - Intermittent.............. Automatic Stop

DESCRIPTION AND OPERATION OF CONTINUOUS TRAIN CONTROL

12. Circuit-Receiving and Amplifying Apparatus.—In Fig. 4 is shown a diagram of the circuit-receiving and amplifying apparatus. A receiver consisting of a laminated iron bar and two coils of wire is mounted to the rear of the pilot and about 6 inches above the rails. The two coils of wire, each in line with a rail, are mounted on the bar. An adjustable condenser in series with the receiver is connected across a portion of the reactor, and another adjustable condenser is connected across the whole reactor. Each vacuum tube is composed of three elements; a filament similar to that of an incandescent light, a grid of meshed wire around the filament, and a cylindrical metal plate that encloses the other two elements. A transformer and a rectifier complete the equipment, the latter being used to change an alternating current to a direct current when a direct-current relay is used.

From the standpoint of safety as well as for other reasons, it is undesirable to have a voltage on the rails that would give a current high enough to operate the direct-current relay; only about 4 volts are used. Although this low current would not induce enough electromotive force in the receiver to operate the relay, yet, by means of an amplifying apparatus, it is possible to make this electromotive force control a current from the headlight generator for the operation of the relay. The minute current produced by the electromotive force induced in the receiver permits a current from the headlight generator to energize the

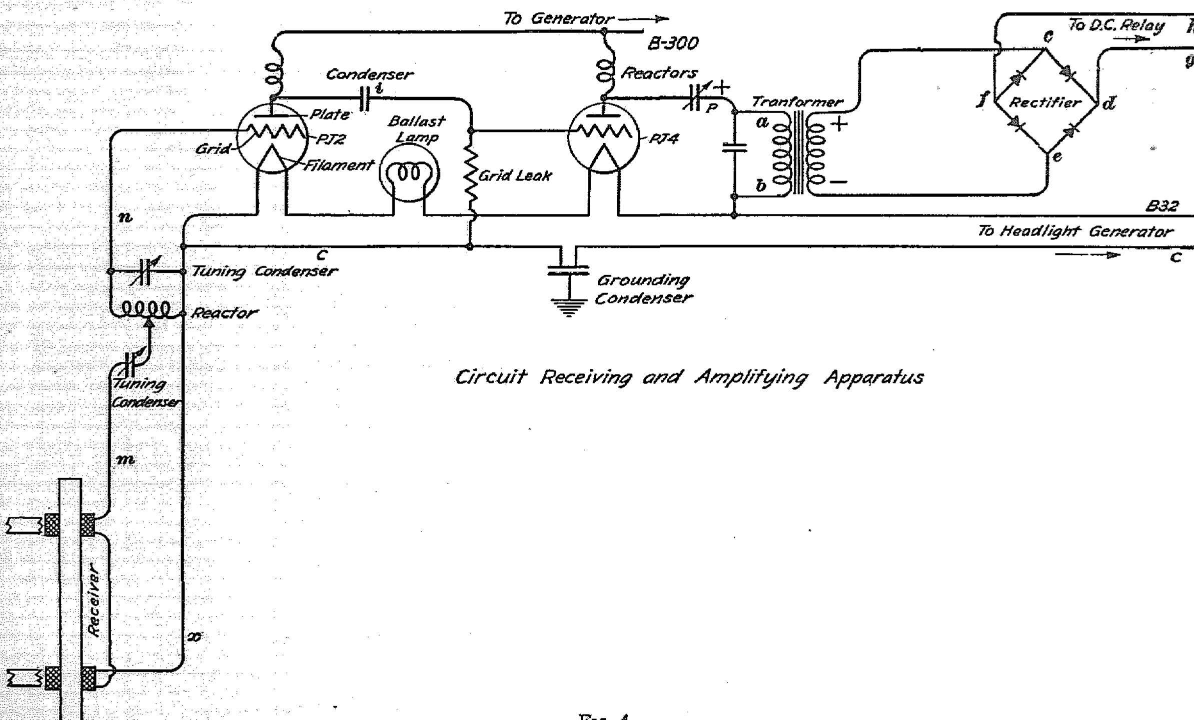
direct-current relay, thereby causing its contact arms to be picked up; an absence of current in the receiver prevents this flow of current through the relay and causes its contact arms to drop.

The manner in which this is accomplished is as follows: it being assumed first that no current is flowing in the receiver circuit. The filaments of the vacuum tubes must be heated; this is accomplished by a circuit from the generator through wire *B32*, hence through one filament, the ballast lamp, the other filament, and then through wire *c* back to the generator. The voltage of the headlight generator fluctuates and the ballast lamp is used to keep the current constant.

A constant direct current flows from the *B300* wire of the generator to the plate of the vacuum tube *PJ2* thence through the tube to the filament, then to the wire *c* of the generator; a current also flows from the *B300* wire to the plate of the vacuum tube *PJ4* through the tube to the filament and the wire *c* of the generator.

The condenser *P* prevents the constant direct current from the generator from passing through the primary coil of the transformer. Even if current were permitted to pass through this coil, the only result would be a loss of energy, because a constant direct current in the primary coil would not induce an alternating current in the secondary coil. With no passage of current through the secondary coil of the transformer and the rectifier, the direct-current relay is deenergized.

13. An entirely different condition exists when an electromotive force is induced into the receiver by current in the rails. A current is now established in a circuit consisting of the receiver, the wires *m*, Fig. 4, the tuning condenser, part of the reactor, and wire *x*. A circuit is formed by wire *n*, the grid and filament of the vacuum tube *PJ2*, the wire, and the reactor that acts as an auto-transformer. This is known as the grid circuit. The alternating current in the grid circuit alternately makes the grid positive and negative with respect to the filament; when the grid is positive the constant direct current in the plate circuit is increased; when the grid is negative the plate-circuit current is decreased; the effect of this is to cause pulsa-



Circuit Receiving and Amplifying Apparatus

Fig. 4

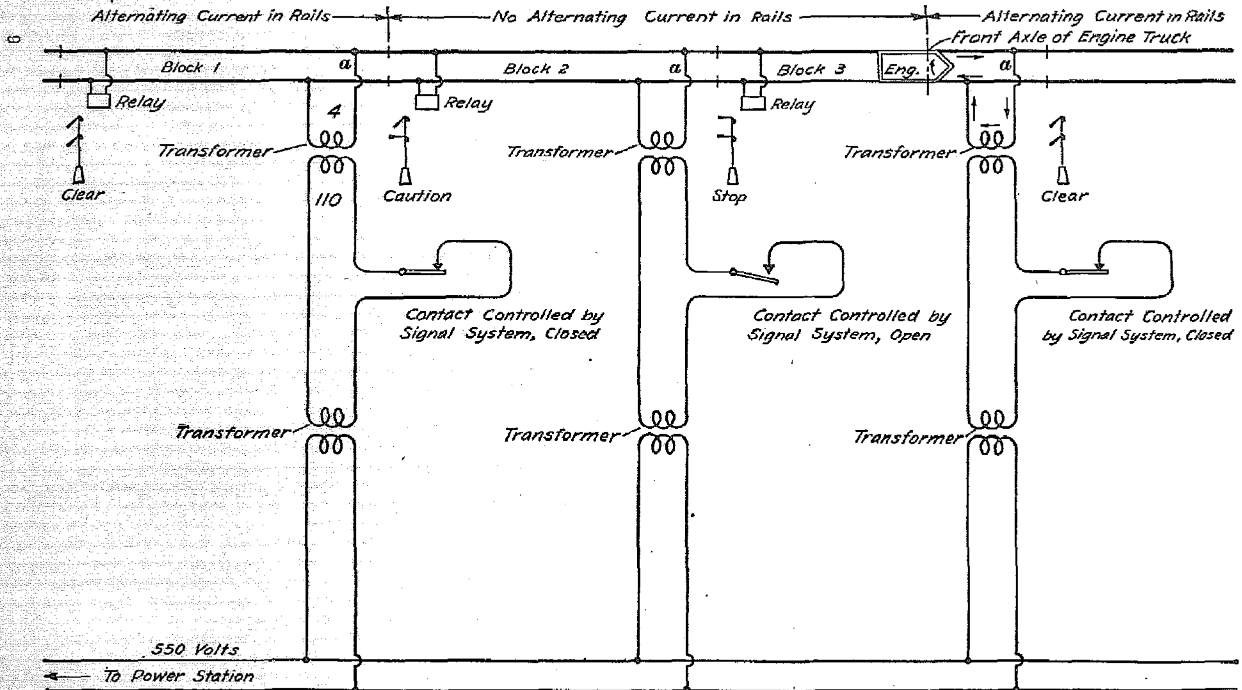
tions in the direct current. However, the pulsations in this current are much greater than the pulsations in the alternating current in the receiver. The pulsations in the plate-circuit current pass through the condenser and are impressed on the grid of the vacuum tube *PJ4*. The action here is similar to that already described and the pulsations in the plate-circuit current are still further increased. The purpose of creating pulsations in the plate circuit of this tube will be apparent from the following: The pulsating direct current in the plate circuit alternately charges and discharges the condenser *P* that causes an alternating current in the primary coil of the transformer. With such a current in the primary coil of the transformer, an alternating current will flow in the secondary coil. The current in this coil is changed to a direct current by the rectifier and energizes the direct-current relay.

14. Summary.—The foregoing may be summarized as follows: A current in the grid circuit of the first vacuum tube creates pulsations in the plate-circuit current of the second vacuum tube, thereby making it possible for a current to pass through the transformer to the direct-current relay. With no current in the grid circuit of the first vacuum tube, no pulsations form in the plate-circuit current, hence a current cannot pass through the condenser to the primary coil of the transformer. Therefore, the purpose of the amplifying apparatus is to create pulsations in a current from the headlight generator when the rails carry a current.

UNION SWITCH AND SIGNAL COMPANY'S TWO-SPEED TRAIN CONTROL

WAYSIDE CIRCUITS AND SIGNAL CIRCUITS

15. Relation Between Circuits.—An alternating current is used in the wayside circuits of continuous train-control systems. The current is supplied from a power station and is conveyed along the right of way on two wires on poles, these wires being connected by means of other wires to the rails at the leaving end of each block as at *a*, Fig. 5. The direction of traffic is here assumed to be from the left to the right end, thus the leaving



Two-Speed Train Control—Wayside Circuits

FIG. 5

point of a block is where the rails of this block are insulated from the rails of the next block ahead as required by the signaling system. The pole line carries about 550 volts; this is stepped down by transformers to about 4 volts across the rails. It is assumed that the signal system uses a direct current.

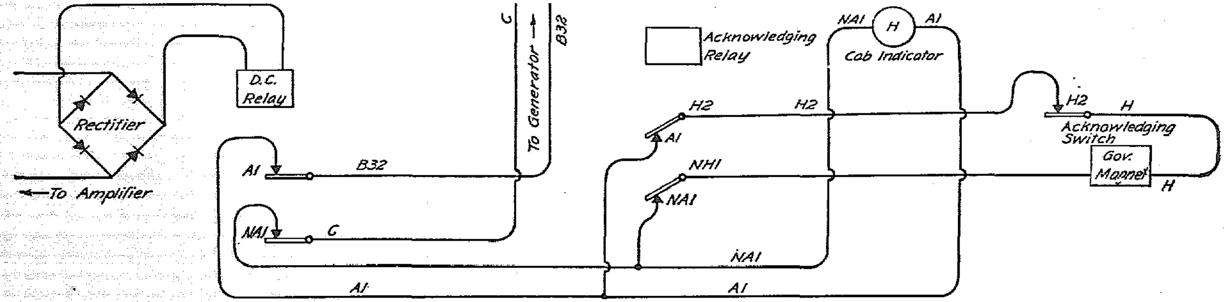
The signal system and the train control wayside circuits are so interconnected that in a clear block, such as *1*, a contact controlled by the signal system is closed. With this contact closed, an alternating current from the wayside circuit flows from the leaving end of the block through one rail, through the relay, and back through the other rail to the point where it entered. No alternating current is flowing through the rails between the caution signal and the stop signal, as in block *2*, because the block signal, when going to stop as shown, opens a contact and breaks the circuit. With an engine in block *3*, an alternating current is flowing from the leaving end of this block, through one rail, thence through the axle of the engine truck to the other rail, and then back to the leaving end. It is assumed, of course, that the block ahead of *3* is unoccupied. In addition to there being no current in block *2*, there is also no current in block *3* between the rear of the engine truck and the entering end of this block.

The foregoing can be summarized by stating that the signal system will permit a flow of alternating current through the rails of a clear block and between the engine and the leaving end of the block it occupies, but no current between the engine and the caution block at the rear.

Owing to the presence of current the engineer of a train moving through block *1* will receive a clear or a green cab signal, commonly called a high light. When the engine passes the caution signal the cab indication, owing to the absence of current, will change to a caution or a low light between this signal and the train shown in block *3*.

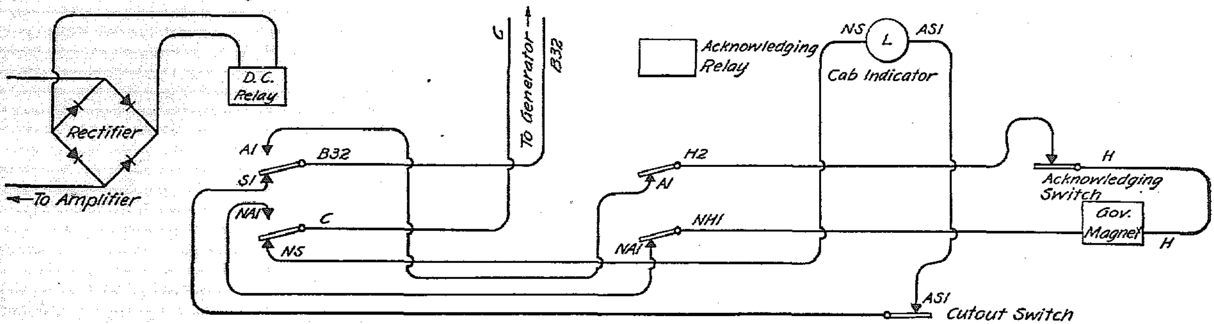
LOCOMOTIVE CIRCUITS

16. Circuits on a High Light.—The simplified wiring diagram in Fig. 6 shows the electrical circuits when running on a high or a green cab indication. As already explained, alternating current is flowing through the track circuit with a green cab



High-Light Circuits

FIG. 6



Low-Light Circuits Before Acknowledging

FIG. 7

indication, and results in the direct-current relay being energized. The upper and lower contact arms of this relay will then be in their upper position as shown. With these arms in this position current flows through the *B32* wire of the headlight generator then through contact *A1* to the wire *A1* and the high light of the cab indicator, thence through the wire and contact *NA1* back to the wire *C* and the generator. This causes the light to burn.

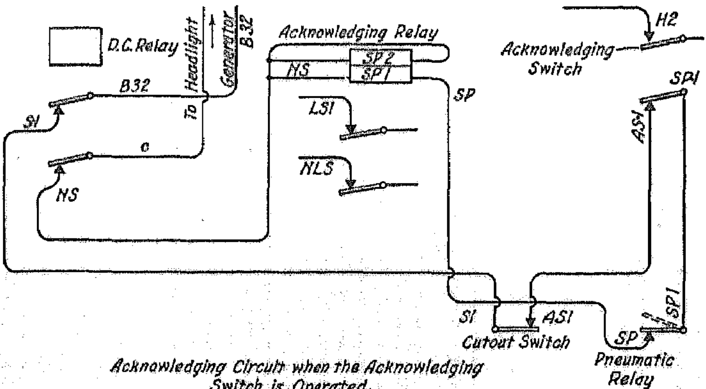
The governor magnet is energized by current from the generator flowing through wire *B32*, contact *A1* and wire *A1* to the contact *A1* of the acknowledging relay, through wire *H2* and the contact *H2* of the acknowledging switch and wire *H* to the governor magnet. The current then passes through the wire *NH1* and the contact *NA1*, through the contact *NA1* at the direct-current relay, and thence to the generator. In brief, the green cab light and the governor magnet are receiving current from the headlight generator.

17. Circuits With a Low Light.—The simplified wiring diagram in Fig. 7 shows the electrical circuits that are established when the cab light changes from green to orange or from high to low. It has already been explained that there is no alternating current flowing through the rails of a caution block, hence, as soon as the receiver on the locomotive enters such a block, the direct-current relay on the locomotive becomes deenergized. This results in the contacts *A1* and *NA1* opening and the contacts *S1* and *NS* closing. This breaks the circuit from the generator to the high light and establishes a circuit from the generator through wire *B32*, contact *S1*, wire *S1*, to the contact *AS1* at the cut-out switch, and thence to the low light. The current then passes through the wire *NS* and contact *NS* to the generator; this lights the low light.

It will be apparent that the opening of the contacts *A1* and *NA1* of the direct-current relay will deenergize the governor magnet.

18. Acknowledging Circuit.—The simplified wiring diagram in Fig. 8 shows the circuit when the acknowledging switch is operated. The purpose of the acknowledging switch is to energize the acknowledging relay.

Operating the acknowledging switch closes the contact *AS1*; current then passes from the generator through wire *B32*, contact *S1*, the cutout switch contact *AS1* of the acknowledging switch, wire *SP1*, contact *SP* of the pneumatic relay, coil *SP1* of the acknowledging relay, and the contact *NS* to the headlight generator. This passage of current energizes the acknowledging relay and causes the contacts *NLS* and *LS1* to close; these contacts will still remain closed when the switch is returned to normal position. The acknowledging circuit can be completed at any train speed, provided the contact *SP* of the pneumatic relay is closed. However, this contact opens and remains open for a predetermined period of time when the train control cuts in, and



Acknowledging Circuit when the Acknowledging Switch is Operated

FIG. 8

during this interval the acknowledging relay cannot be energized. The acknowledging circuit can only be closed on a low light owing to the contacts *S1* and *NS* of the direct-current relay being closed as shown.

After the acknowledging relay is once energized, it remains so until the direct-current relay is energized as shown by the cab indication changing from a low to a high light. With the direct-current relay contacts *NS* and *S1* open, the acknowledging circuit is broken and this relay is deenergized; the contacts *LS1* and *NLS* then open.

The acknowledging switch has two sets of contacts, *H2* and *AS1*; in normal position, *H2* is closed and *AS1* is open. As *H2*

is in the governor-magnet circuit, the magnet will be deenergized when the acknowledging switch is moved from normal position. Therefore, the train control will cut in if the switch is held away from normal position for more than a predetermined interval, or the time required for the timing valve to seat.

19. Low Speed Circuit.—The purpose of the low-speed circuit, Fig. 9, is to permit the governor magnet to be energized at speeds less than the low-speed limit. With the governor magnet energized, the train can proceed at less than the low-speed limit without the brakes being applied by the train control.

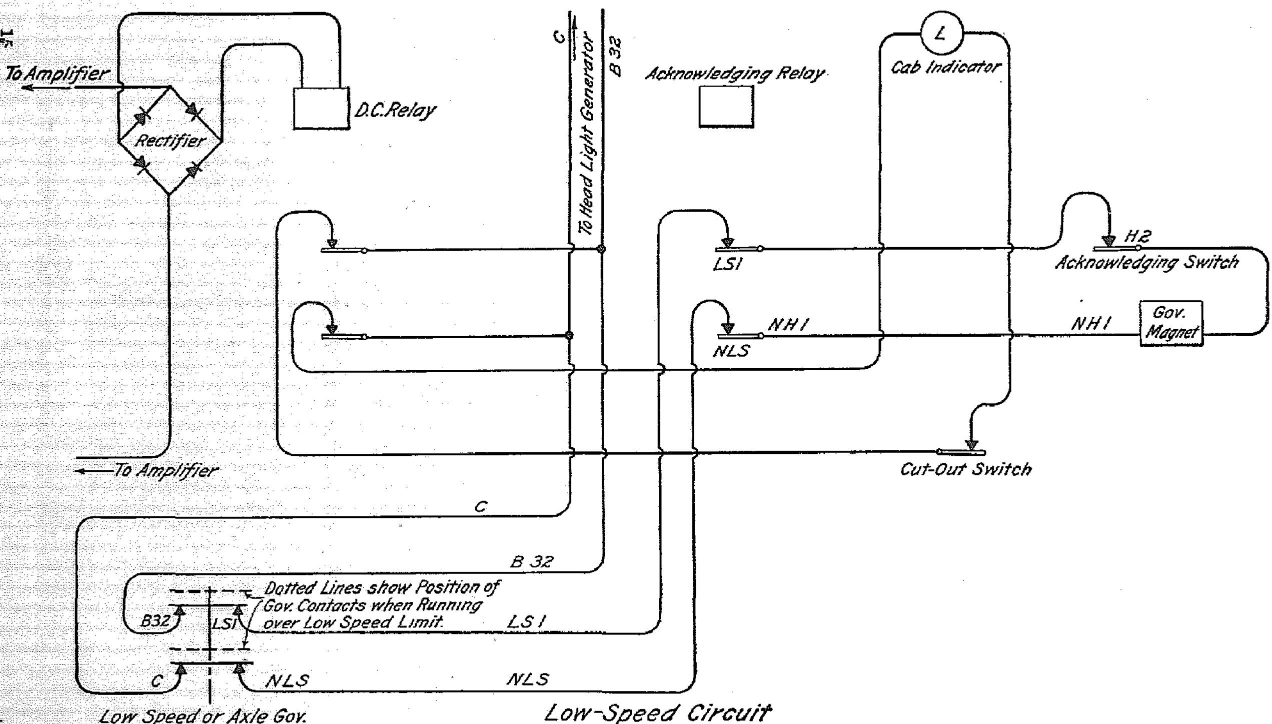
When the acknowledging switch is returned to normal position, the governor-magnet circuit is closed at this point. With the speed under the low-speed limit, the contacts at the axle governor are closed, as shown by the full lines. The low-speed circuit is then completed through wire *B32*, the contacts *B32* and *LS1* of the axle governor to wire *LS1*, the contact *LS1* of the acknowledging relay, contact *H2* of the acknowledging switch, the governor magnet, contact *NLS* of the acknowledging relay, wire *NLS*, contacts *NLS* and *C* of the axle governor to wire *C* and the generator. The current through this circuit energizes the governor magnet. This circuit will be broken at speeds above the low-speed limit because the contacts at the low-speed governor then assume the position shown by the dotted lines.

Three requirements must be met in order to complete the low-speed circuit: The acknowledging relay must be energized by the acknowledging circuit in order to pick up its contacts; the acknowledging switch must be returned to normal position; the speed must be below the low-speed limit.

THREE-SPEED AUTOMATIC TRAIN CONTROL

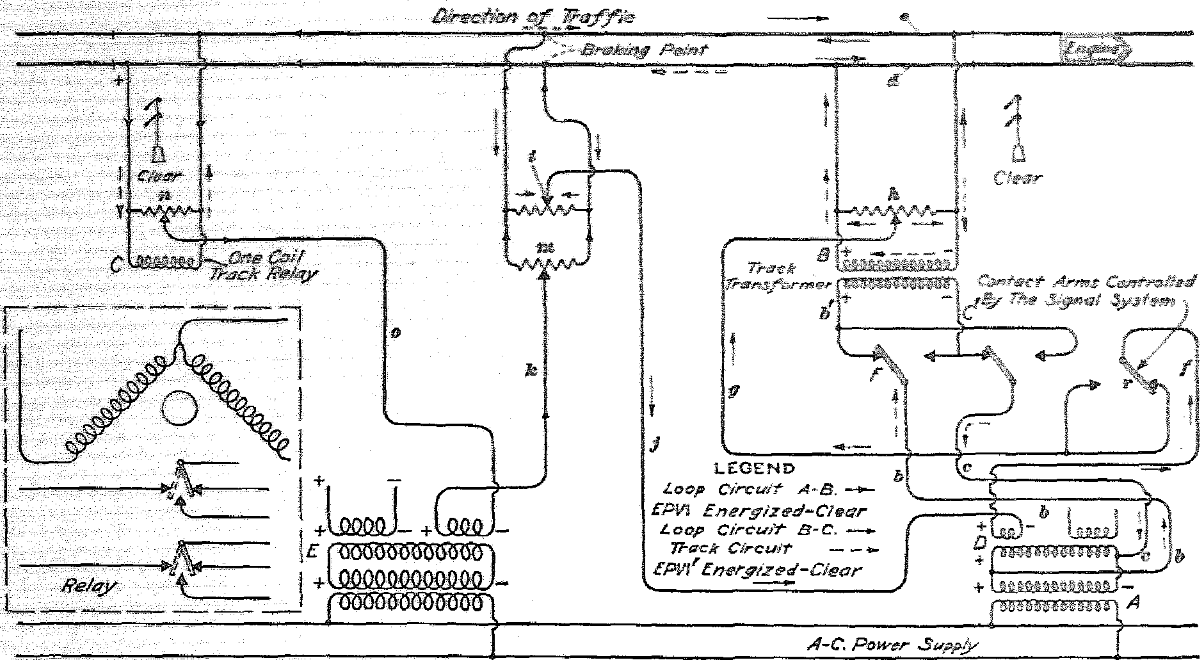
WAYSIDE CIRCUITS AND SIGNAL CIRCUITS

20. Relation Between Circuits.—In Fig. 10 is a wiring diagram that shows the relation between the wayside circuits and the signal circuits of a three-speed train-control system. As an alternating current is used in both the train-control and the signal circuits, the plus and minus signs and the arrows must be considered as representing instantaneous direction of current only.



Low-Speed Circuit

FIG. 9



Three-Speed Train Control—Wayside Circuits

FIG. 10

A three-speed train-control system requires three cab indications and in order to obtain them, the train-control relay must be capable of assuming three positions; it will now be shown how this is done. The relay has two coils; one connected to the track receiver, which in turn is energized by the track circuit, and the other coil connected to the loop receiver that is energized by the loop circuit. If a certain relation exists between the direction of these currents, as, for example, if each current is flowing in the direction indicated by the arrow, a high light will be obtained. If the current in the coil connected to the track receiver is reversed and the current in the other coil remains the same, then a medium light will be obtained. If either one of these coils is deprived of current, a low light will be obtained. It will now be explained how the track circuits are arranged to bring about the foregoing conditions in the train-control relay.

Starting at the transformer A, the current in the track circuit leaves the positive terminal of the secondary coil of the transformer and passes through the wires b and b' to the primary of the track transformer B, thence through the wires C' and c to the transformer A. The current in the primary coil of the transformer B causes a current to flow through the secondary coil and rail d to one line of the track relay C, thence through rail e, and back to the secondary coil of the track transformer B. It will be assumed that this flow of current in the track circuit, as indicated by the dotted arrows, will cause a flow of current in the train-control relay coil connected to the track receiver in the direction of the arrow.

21. Starting at the secondary coil of the transformer D, the current in the loop circuit passes through the wire f, contact arm of the track relay, and the wire g to the middle of the resistor h. The current then flows in each direction to the rails d and e to the braking point and to the outside ends of the resistor i, then from the middle of the resistor to wire j and back to the transformer D. This circuit is indicated by the arrow shown in full lines. The current in this direction will cause current to flow through the train-control relay coil connected to the loop circuit, as indicated by its arrow. This circuit is only effective

on a locomotive between the braking point and the signal ahead, and if this signal is at *clear*, a high light will be obtained as already explained. Another loop circuit is completed from the transformer E, through the wire k, the middle of the resistor m, and through that portion of the rails d and e to the left of the braking point, to the resistor n, to wire o, and back to the transformer E. The current in this loop circuit flows in the same direction as in the other loop circuit. Therefore, with a train in the section to the left of the braking point and the signal ahead at *clear*, the condition in the loop-receiver coil of the relay remains unchanged and the high light will be obtained. It will be noted that the track circuit is effective on the train in any part of the block.

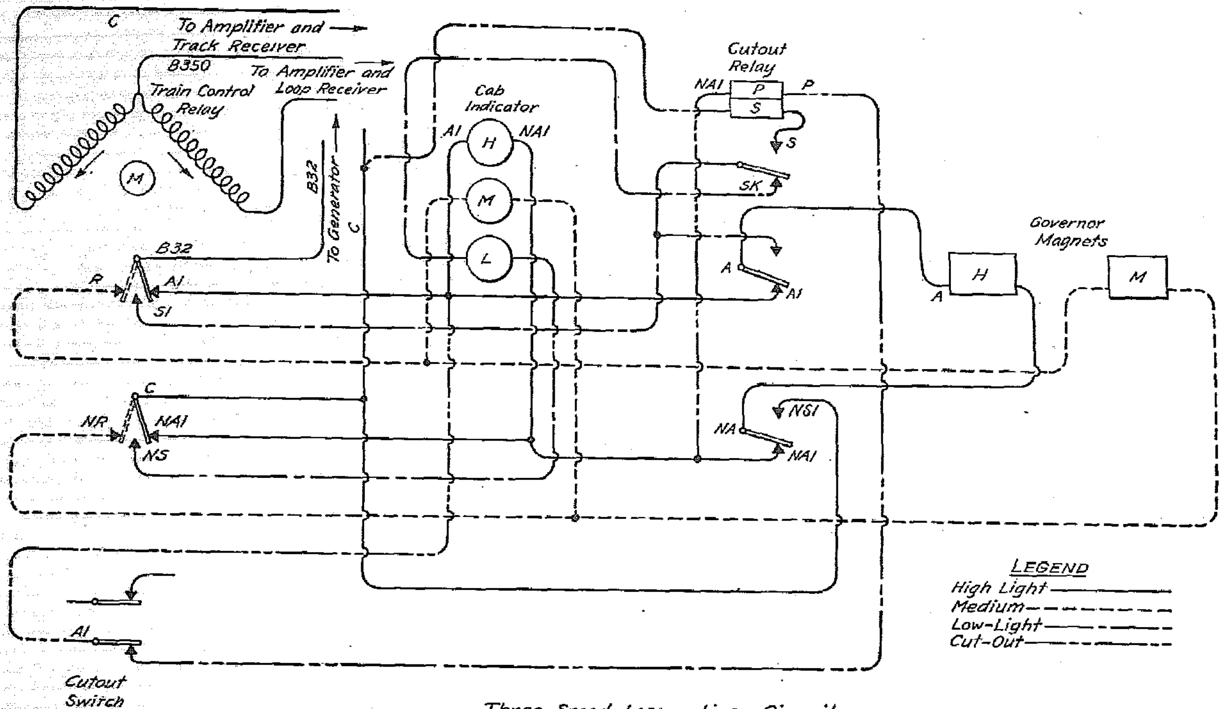
22. It will be assumed, next, that there is an engine in the next block to the one shown. The signal behind the engine will now be at *stop* and the other one will be at *caution*. The action of the signal system is now such as to cause the contact arm r to assume a vertical position, thereby opening the loop circuit; also, the signal system causes the two contact arms of the switch F to move to the right. This latter results in the reversal of the current in the track circuit; that is, the current now flows from b to C' and thence from b' to c. Reversing the current in the primary coil of the transformer results in a reversal of current in the secondary coil and in the track rails. Under these conditions the track receiver of an engine passing the caution signal will receive a reversed track current with the result that the current in the train-control relay coil will also be reversed. The current in the other coil will remain as before, because the loop circuit between the caution signal and the braking is active. The result is that the cab indication will change from high to medium. It is now assumed that the engine next passes the braking point. The track circuit will remain the same as before; that is, it is reversed, but the engine has passed off the previous loop circuit and onto the other one. But this latter loop circuit is open, as already explained, hence the coil of the relay is deprived of current. The result is that the cab indication changes from a medium to a low light.

23. It is next assumed that the engine passes the stop signal; owing to the first engine, there will be no current in the track circuit between this engine and the stop signal, therefore the track-receiver relay coil on the second engine will be deprived of current. The loop circuit in the block is active and this coil of the relay will be energized; the result will be that the engine will continue to operate on a low light. It will be noted that the current in the loop circuit is passing through both rails in the same direction and hence is not short-circuited by the first engine as is the track circuit.

LOCOMOTIVE CIRCUITS

24. Receivers.—A three-speed train-control system requires two receivers, the track-circuit receiver and the loop-circuit receiver. The track-circuit receiver is placed behind the pilot as with the two-speed system, the other is placed at the rear of the tender. The track-circuit receiver is not affected by the current in the loop circuit, neither is the loop-circuit receiver affected by the current in the track circuit. The two coils of the track receiver are so connected that the electromotive forces induced in them by the current in the loop circuit oppose each other and are thereby neutralized. Also, in the loop-circuit receiver, the coils are so connected that the two electromotive forces induced by the current in the track circuit are in opposition and hence neutralize each other.

25. Circuits on a High Light.—Both coils of the relay *M*, Fig. 11, are energized on a high light; one by the track circuit, the other by the loop circuit. Under such conditions, the contact arms will move to the right and make contact at *A1* and *NA1*. A circuit is then completed through the wire *B32*, the contact *A1* to a similar contact at the cab indicator, thence to the wire *NA1* and contact *NA1* to the wire *C*. This circuit causes the high light to burn. Another circuit is completed through the wire *B32*, contact *A1*, the middle contact arm of the cut-out relay, the governor magnet *H*, to the lower contact *NA1*, thence to the wire *C*. This circuit energizes the high-speed governor magnet.



Three Speed Locomotive Circuit
FIG. 11

26. Circuits On a Medium Speed Light.—On a medium-speed light, the current through the track-circuit coil of the relay has been reversed with respect to the other one, thereby causing the contact arms to move to the left. A circuit is then completed through wire *B32*, Fig. 11, contact *R*, the light *M* of the cab indicator, contact *NR* to wire *C*. A circuit is also established to the medium-speed governor through wire *B32*, contact *R*, the governor *M*, and contact *NR* to wire *C*.

27. Circuits On a Low Light.—On a low light either one of the relay coils may be deenergized. The contact arms then assume a middle position, thereby completing a circuit through wire *B32*, Fig. 11, contact *S1*, the light *L* of the cab indicator, contact *NS* to wire *C*. In this case neither governor magnet is energized, and this enforces the low speed limit. Each change of signals to a more restrictive condition requires acknowledgement to prevent the train control from operating. With this equipment, acknowledging is done pneumatically.

28. Cut-Out Circuit.—The purpose of the cut-out circuit is to cut out the equipment when the locomotive is to operate in territory not equipped with train control. If means were not provided to cut out the train control, the train would have to be operated at the low-speed limit. At the time of cutting out, the engine must be moving on a section of track equipped with a special loop circuit carrying a high current. The cut-out switch is then closed, which completes a circuit through wire *B32*, contact *A1* of the train control relay, the cut-out switch, coil *P* of the cut-out relay, and contact *NA1* of the train-control relay to wire *C*. This pulls the three contact arms of the cut-out relay into their upper positions. When the engine passes off the section of track equipped with the loop circuit, the train-control relay will be deenergized and its contact arms will assume the low-speed position. A stick circuit is now completed through wire *B32*, contact *S1*, the upper contact arm of the cut-out relay and coil *S* to wire *C*. The cut-out switch is next returned to normal position, thereby completing a circuit through wire *B32*, contact *S1*, the middle contact arm of the cut-out relay, the governor magnet *H*, the lower contact arm of the cut-out relay to

wire *C*. This circuit keeps the high-speed governor magnet energized, and permits the train to be operated without interference from the train control. The train control is automatically cut in when the engine again enters train-control territory. This is done by the train control relay becoming energized and thus breaking the stick circuit of the cut-out relay.

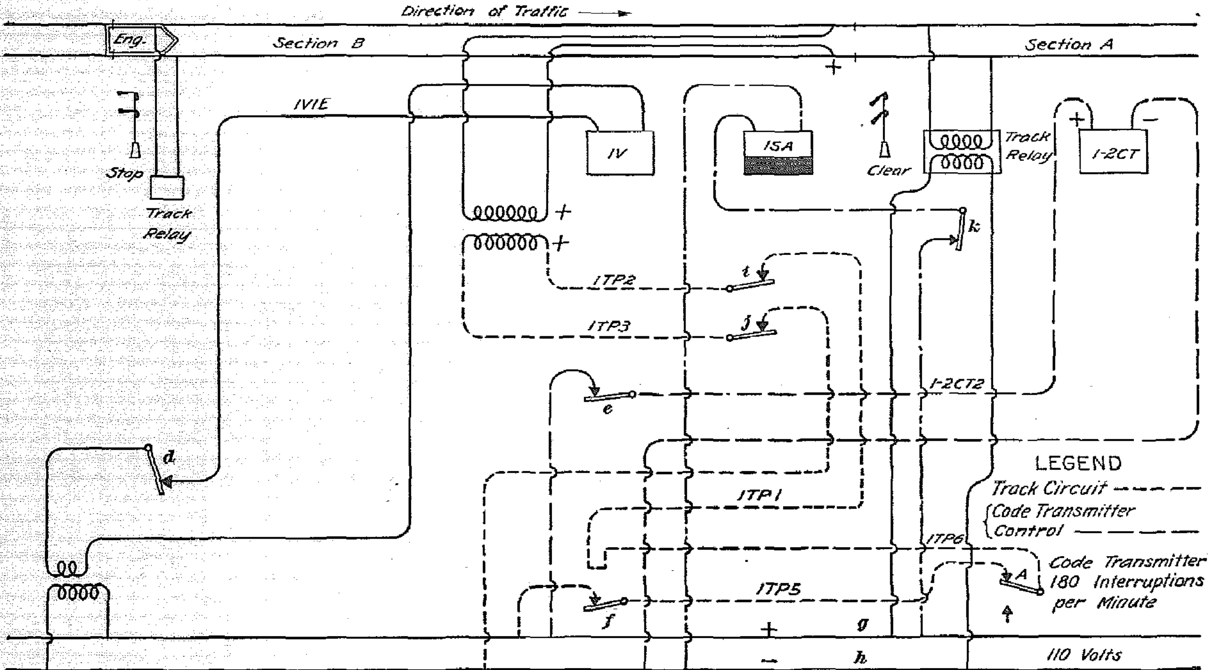
CODE SYSTEM

WAYSIDE CIRCUITS AND SIGNAL CIRCUITS

29. **Relation Between Circuits.**—Where more than three cab indications are to be used it becomes impossible to use the track and loop circuits of the two- and three-speed systems to control the locomotive equipment; instead, it becomes necessary to code the current to the rails. The term *code* here means that the current is interrupted; that is, the circuit is opened and closed a certain number of times per minute, in this instance, 180, 120, and 80 times. One relay on the engine is tuned to pick up only on 180 interruptions per minute, another relay only on 120, another only on 80, each relay controlling the current to its particular cab indication. A fourth cab indication will be given when none of the relays are picked up.

The relation between the signal system, which in this case uses alternating current, and the wayside train-control circuits with an engine entering a clear block is shown in Fig. 12. Owing to section *A* being clear, the track relay of the signal system in this section is energized by the signal circuit, thus moving the contact arm *k* to the left. This completes a circuit from line *g* of the 110-volt line through the contact arm *k* and the relay *ISA* to the line *h*; this energizes the relay *ISA* and pulls the contacts *i* and *j* into their upper position.

The track relay of section *B* will be deenergized as soon as the engine enters this section; this permits the contact arm *d* to drop down and close a circuit. This circuit will cause the relay *IV* to be energized and the contact arms *e* and *f* to move up and close their contacts. The contact arm *e* completes a circuit from line *g*, contact arm *e*, wire *1-2CT2* to relay *1-2CT* to line *h*, thus energizing relay *1-2CT*. This relay now starts a motor that



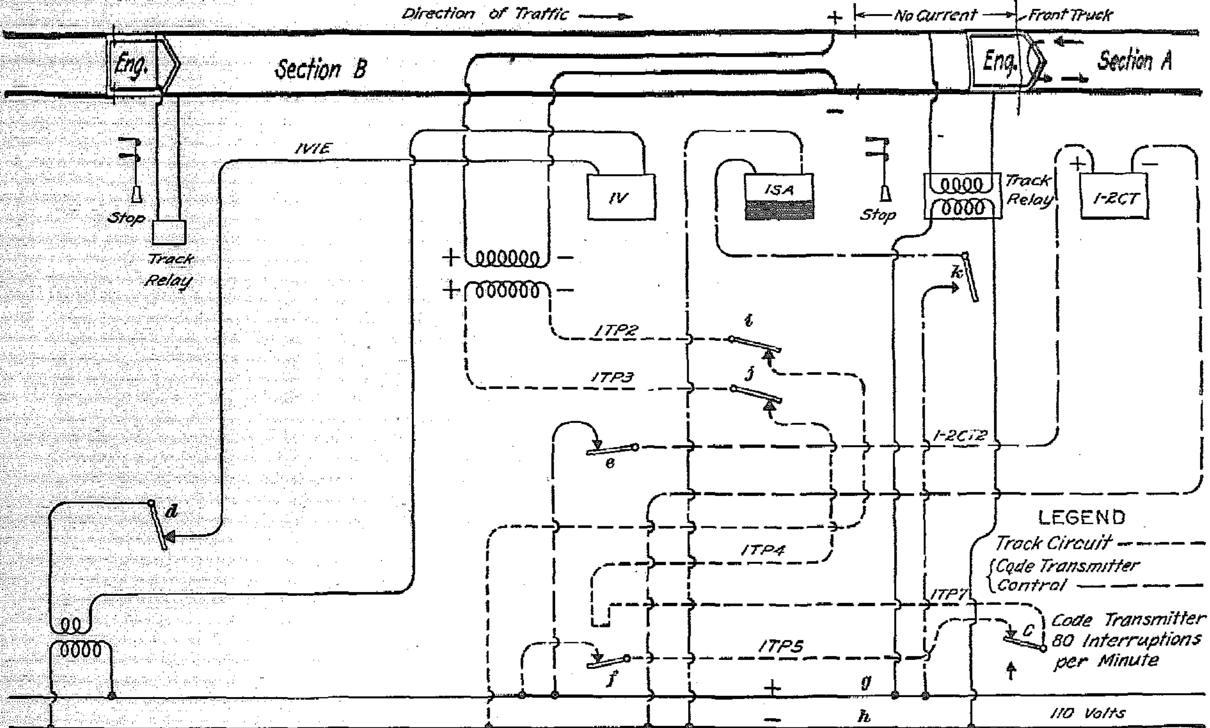
Wayside Circuit Clear Block

FIG. 12

operates the code transmitter. A primary circuit is also completed from line *g* through contact arm *f*, wire *ITP5*, and contact arm *A* of the code transmitter. From the code transmitter the circuit is completed through wire *ITP6*, wire *ITP1*, contact arm *i*, wire *ITP2* to one coil of the transformer, thence to wire *ITP3* and contact *j* to line *h*. This current induces an electromotive force and causes a current to flow in the secondary circuit, comprising the secondary coil of the transformer, one track rail, the engine-truck axle, and the other rail. The contact *A* of the code transmitter makes and breaks the primary circuit 180 times per minute, therefore the current in the secondary circuit is interrupted the same number of times. The effect of the current in the secondary circuit is to induce an electromotive force in the receiver on the engine, this electromotive force finally resulting in a green cab indication.

The foregoing may be summarized as follows: Relay *IV* is energized and picks up contact *e*; this starts the motor of the code transmitter. The contact *f*, picked up with *e*, and the code transmitter control the current from the 110-volt line to the primary of the transformer; a similar current flows in the secondary circuit.

30. If section *A*, Fig. 13, is occupied when the engine enters section *B*, the track relay in section *A* will be deenergized owing to the train in this section. The relay *ISA* will then be deenergized because the contact *k* is opened; this permits the contact arms *i* and *j* to drop and make contacts in their lower positions. The relay *IV* will be energized through the same circuit as before, thereby completing a circuit through the motor of the code transmitter as already explained. When the contact arm *f* is picked up by the relay *IV*, a circuit is completed from line *g*, through contact arm *f*, wire *ITP5*, the contact *C* of the code transmitter, wires *ITP7* and *ITP4*, contact *j*, to the primary coil of the transformer, thence to contact arm *i* and line *h*. This current induces an electromotive force in the secondary circuit as already explained. The contact arm *C* of the code transmitter makes and breaks the primary circuit 80 times per minute, therefore the current in the secondary circuit is interrupted the same num-



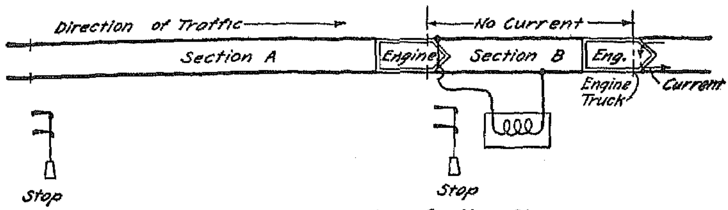
Wayside Circuit- Approach

FIG. 13

ber of times. This finally results in an approach cab indication.

With the condition shown in Fig. 14, there is no current in the rails between the head engine and the block at the rear. If the engine in section *A* enters section *B*, a caution-slow cab indication will be given.

31. The circuits when the current is coded 120 interruptions per minute are not shown. These are made, as already explained, by using another contact on the contact arm of the code transmitter; another line relay will also have to be used in the signal system.



Wayside Circuits - Caution-Slow.

FIG. 14

32. With no engine in either section *A* or *B*, Fig. 15, the track relay of section *A* will be energized and the contact *d* will be open. The relay *IV* will be deenergized, permitting the contact arms *e* and *f*, Fig. 13, to drop to their lower position. The circuit is now completed from the plus of the autotransformer to contact arm *b* through wire *ITP1*, contact *i*, wire *ITP2*, the primary coil of the transformer, wire *ITP3*, and contact arm *j* to line *h*. This gives a continuous alternating current in the primary circuit; a similar current flows in the secondary circuit.

33. If an engine is in section *B*, Fig. 15, the track relay of this section and relay *ISA* will be deenergized and contact arms *i* and *j* will drop into their lower positions. A circuit is then completed from the plus of the autotransformer through the contact arm *a*, wire *ITP4*, contact *j*, wire *ITP3*, the primary coil of the transformer, wire *ITP2*, contact arm *i*, and back to the line *h*. There is now a continuous alternating current in the rails of section *A* but in the reverse direction as before; this throws the signal to approach.

LOCOMOTIVE CIRCUITS

34. Description.—The receiver *D*, Fig. 16, the amplifier *E*, and the transformer *F*, operate in the same manner as similar equipment already explained with the two-speed system. However, the master relay *G* replaces the *D.C.* relay of the two-speed system. The master-relay magnet is connected to one coil of

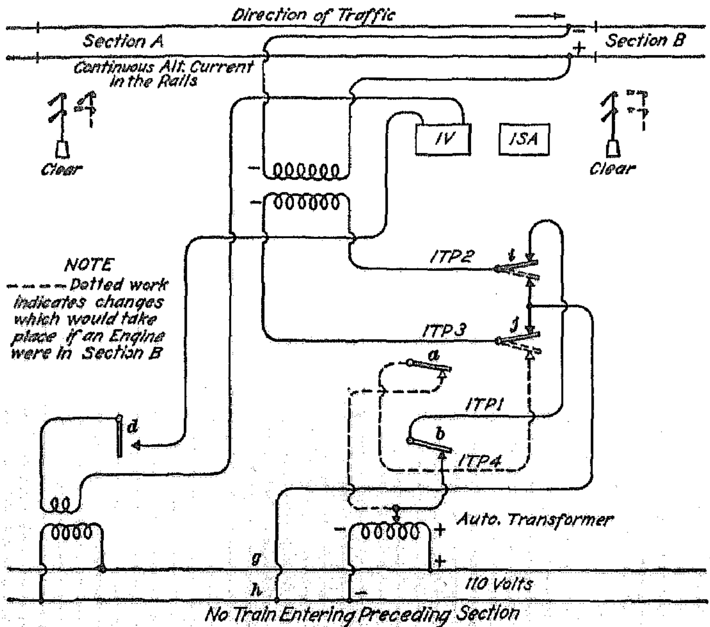


FIG. 15

the transformer. The contact arm *a* of this relay is pivoted so that it swings back and forth between two contacts *b* and *f* according to the increase and decrease in the plate current in the amplifier and hence in the relay coil. In the position of the arm shown, the current flows from the *B32* wire of the headlight generator through arm *a*, contact *b*, coil *d* of the transformer *K* to the wire *c* of the headlight generator in the direction of the arrow. With the arm against the other contact *f*, the current flows through the wire *B32* of the generator, through

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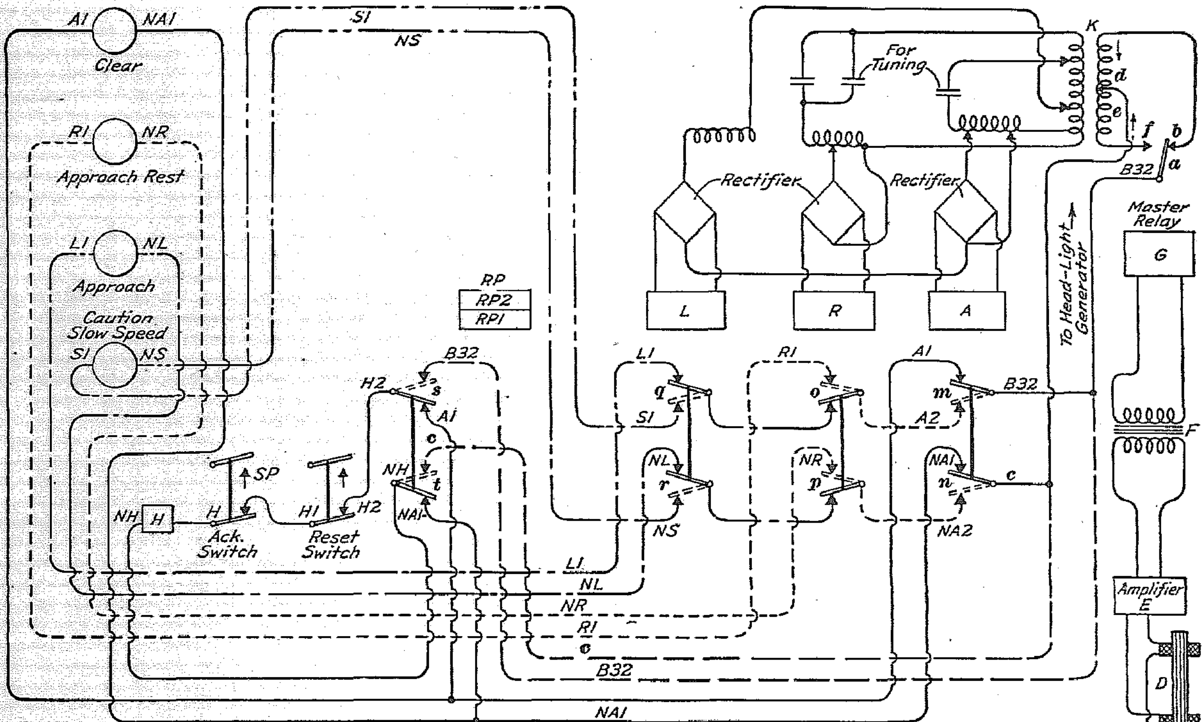


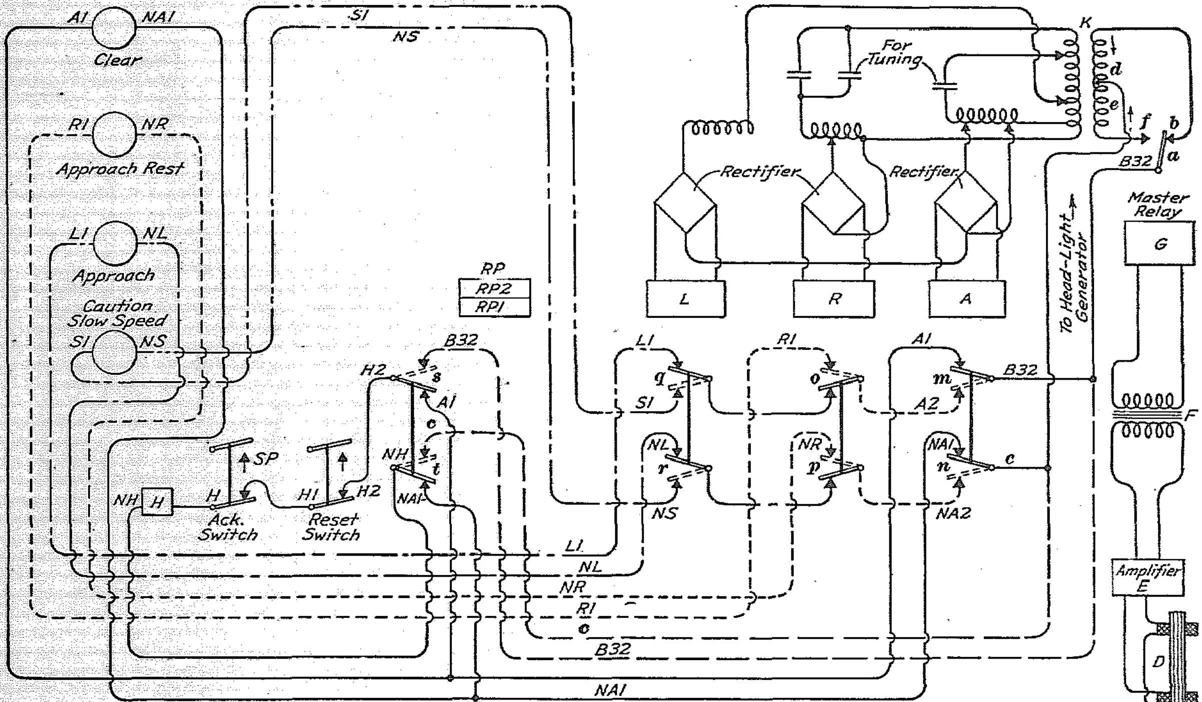
Magnet Circuits

Fig. 16

arm *a* and contact *f*, and coil *e* of the transformer to the wire *c* of the generator. In this case, the current is flowing in the reverse direction, as shown by the dotted arrow. This vibratory action of the contact arm induces an alternating current in the secondary coil of the transformer. This coil has a number of taps so that the amount of current flowing to the three rectifiers can be regulated. Condensers and reactors are arranged to tune the various relays so as to make them pick up on a particular code. The relay *A* is tuned to pick up its contact arms when the current in the rail is interrupted 180 times a minute; under any other condition of rail circuit, the contact arms *m* and *n* will assume the positions shown by the dotted lines. The relay *R* is tuned to pick up its contact arms *o* and *p* only on 120 interruptions, the relay *L* is so tuned that its contact arms *q* and *r* will be picked up on any code. However, if there is a continuous alternating current or no current in the rails, these latter contact arms will assume their lower positions.

35. If the train is moving in a clear block, the relay *A*, Fig. 16, being tuned to 180 code, will then pick up the contact arms *m* and *n*. Current will then flow from the wire *B32* of the generator contact arm *m*, contact and wire *A1* to the green light in the cab, then back to the generator through wire *NA1*, contact arm *n*, and wire *c*. This gives the engineer a clear cab indication. A tap is taken off wire *A1* and from this wire the current passes through the contact *A1* and arm *s* of acknowledging relay *RP* to one arm of the reset switch and to one arm of the acknowledging switch to the electric-pneumatic valve *H*, then through wire *NH*, contact arm *t* and contact *NA1* of the acknowledging relay *RP*, to the wire *NA1*. This circuit keeps the valve *H* energized on a clear light and keeps the brake from applying.

36. It will be assumed next that the train approaches an approach restricting block, where a 120-code current will be put in the rails. The contact arms *m* and *n*, Fig. 16, of relay *A* will now assume their lower positions. This will put out the green light and will also deenergize the magnet valve. The relay *R*, being tuned to a 120 code, will pick up its contact



Magnet Circuits

FIG. 16

arms p and o into the position shown by the dotted lines. The current then passes through the wire $B32$, contact arm m of relay A to the contact arm o of relay R, through the wire $R1$, shown by the dotted line, to the approach restricting light, thence back through wire NR, contact arm p of relay R and contact arm n to wire c of the generator.

With the electropneumatic valve deenergized on the change of cab indications, this valve must be energized within 6 seconds, otherwise the brakes will apply. The engineer acknowledges by operating an acknowledging switch and thus picking up the arms s and t of the acknowledging relay RP, thereby energizing the electropneumatic valve. The following circuit is then made: From wire $B32$, arm s of the relay RP, wire $H2$ to one arm of the reset switch, one arm of the acknowledging switch, the electropneumatic valve, and thence through wire NH, contact t, and wire c to the generator. With the electropneumatic valve energized, the brakes are prevented from applying.

37. If the train enters an approach block, the 80 code becomes effective. It has already been stated that the contact arms q and r of the L relay remain in their upper positions with any code. However, the contact arms of the R relay drop down on the 80 code; the contact arms of the A relay are already down.

The current from the headlight generator passes through wire $B32$, the contact arms m and o, of the A and R relays, and the contact arm q of the L relay, thence through wire $L1$ to the approach light. The current then passes through the wire NL and the contact arms r, p, and n to wire c and the generator. When entering an approach block, the contacts s and t that were previously pulled up by the operation of the acknowledging switch, drop down and deenergize the electropneumatic valve. These contacts must be picked up again on the change in cab indications, otherwise the brakes will apply. The operation of the acknowledging switch will make the same circuit as before, hence the contacts s and t will be pulled up and the electropneumatic valve will again be energized.

It must be remembered that the arms s and t of the acknowledging relay always drop down as each change of cab indication

becomes more restrictive, this then requiring acknowledgement on each change. The above will be explained when the acknowledging circuits are taken up later.

38. It is next assumed that the train approaches a caution slow-speed signal; as already explained, there is now no current in the rails. The contact arms *q* and *r* of the *L* relay now drop, and the current from the generator will pass through the upper arms *m*, *o*, and *q* of the respective relays; thence through wire *S1* to the caution slow-speed cab indication, thence through the wire *NS* and through the contact arms *r*, *p*, and *n* to wire *c*, and the generator. The contact arms *s* and *t* drop down as before and they must be picked up by the acknowledging circuit in order to reenergize the electropneumatic valve that was deenergized when these arms dropped on the change of cab indications.

39. Acknowledging Circuit.—A detached diagram of the acknowledging circuit is shown in Fig. 17. The stick relays are shown at *SP*, *LP*, and *RP*. This type of relay is so arranged that the contacts once picked up will remain up, even after the pick-up circuit is opened. It must be remembered that each change of cab indication to a more restrictive condition must be acknowledged, otherwise the electropneumatic valve will remain deenergized and the brakes will automatically apply.

If the cab indication changes from a clear to an approach-restricting, this causes the relay *A* to drop its contact arms, and the relay *R* to lift its contact arms to an upper position, although here shown down. The engineer now closes his acknowledging switch and completes a circuit from *B32* of the headlight generator to the upper contact arm of relay *A*, through wire *A2*, to the contact arm of the pneumatic relay and the acknowledging switch to wire *SP*, relay coil *SP1* of the relay *SP* to wire *NA2* and the lower contact arm of relay *A* to wire *C* of the headlight generator. This circuit causes relay *SP* to lift its contact arms into their upper position.

This action completes a circuit from a tap *1* of *A2* wire through the lower contact arm of relay *SP* and coil *LP2* to wire *NA2* and thence back to the generator. This circuit causes the contact arms of relay *LP* to move to their upper positions.

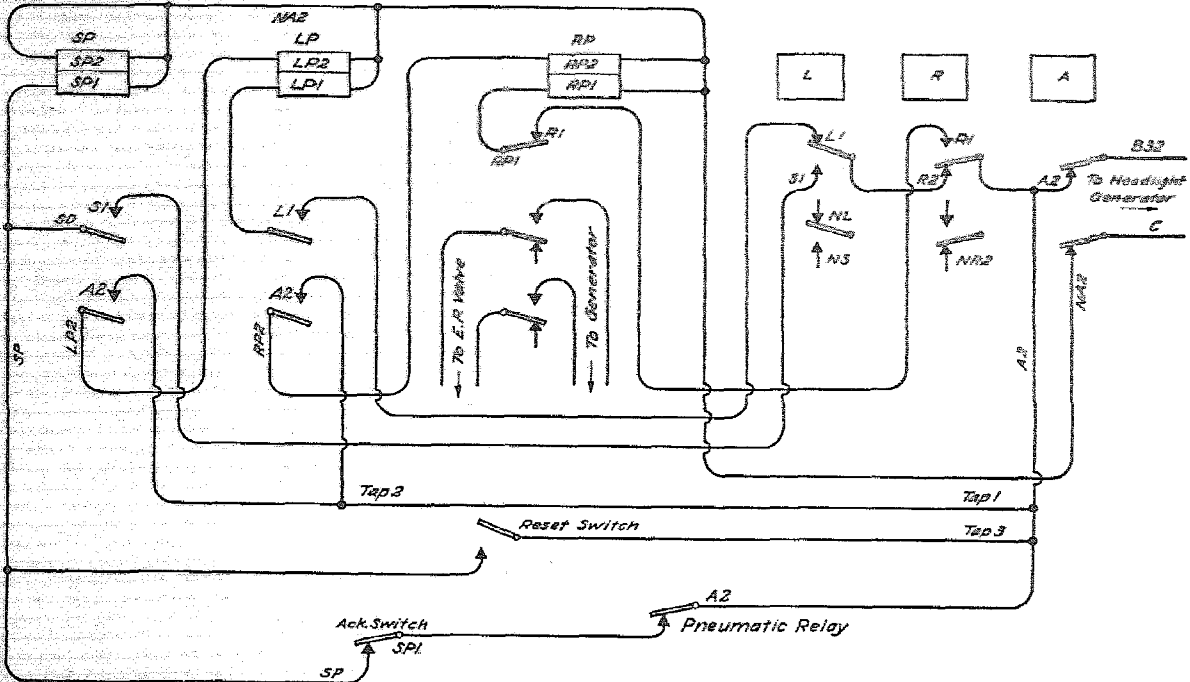


FIG. 17 Acknowledging Circuits

This in turn completes another circuit from tap *2*, through the lower contact arm of relay *LP* to coil *RP2* and to wire *NA2*, then back to the generator as before. This circuit causes the relay *RP* to move its contact arms to their upper position.

A stick circuit is now completed from *B32*, upper contact arm of relay *A* to upper contact arm of relay *R*, which is now in its upper position, to wire *R1*, upper contact arm of relay *RP*, coil *RP1* to wire *NA2* and back to the generator. This circuit keeps the relay *RP* from dropping its contact arms, when the acknowledging circuit is broken after acknowledging.

When the engineer opens his acknowledging switch the relays *SP* and *LP* drop their contact arms into their lower positions. A circuit is now completed from the generator to the electropneumatic valve by the middle and the lower contact arms of relay *RP* as previously shown in Fig. 16, and reenergizes the valve.

The foregoing shows that the three relays pick up their contact arms when the acknowledging circuit is closed, and that two of them drop their contact arms when the circuit is opened, the contact arms of the other relay being held up by the stick circuit.

40. It is next assumed that the cab indication changes from an approach restrictive to an approach light. The relay *R*, Fig. 17, now drops its contact arms and opens the stick circuit of relay *RP*, it being noted that this circuit was completed through the upper contact arm of relay *R*. The breaking of the stick circuit deenergizes relay *RP* and permits its contact arms to drop, thereby deenergizing the electropneumatic valve.

The engineer again closes his acknowledging switch, and in so doing completes the circuit through relay *SP* as before. This in turn completes the circuit through all the acknowledging relays as before, and picks up all of the contact arms of those relays. A stick circuit is now completed from *B32*, upper contact arms of relays *A*, *R*, and *L*, the upper contact arm of relay *LP*, coil *LP1*, wire *NA2*, and thence to wire *C* of the generator. The stick circuit keeps the contact arms of relay *LP* in their upper position, even after the acknowledging switch is open. The stick circuit of relay *RP* is completed as before.

The foregoing may be summarized by stating that two of the acknowledging relays hold their contact arms in their upper position, and the other relay drops its arms.

The magnet valve is energized through the middle and lower contact arms of relay *RP* as before, and thus prevents the brakes from applying.

41. Next it is assumed that the cab indication changes from an approach to a caution slow-speed light. In this case relay *L* is deenergized and its contact arms drop into their lower positions. The stick circuit through contact *L1* is now broken, and the acknowledging relay *LP* drops its contact arms; this in turn breaks the stick circuit of relay *RP*, causing its contact arms to drop. This latter action deenergizes the magnet valve, which must be now reenergized to prevent an automatic brake application.

When the acknowledging switch is closed, the relays *SP*, *LP*, and *RP* are energized through the same circuit as before, thus picking up their contact arms. A stick circuit is now established from *B32*, through the upper contact arms of the relays *A*, *R*, and *L*, wire *S1*, upper contact arm of the relay *SP*, coil *SP1* and wire *NA2* and back to the generator. The stick circuits of relays *LP* and *RP* are now completed as before. This can be summarized by stating that the contact arms of all three acknowledging relays are held in their upper positions. The magnet valve is now energized through the middle and lower contact arms of relay *RP*.

42. Reset Circuit.—If the brakes are applied automatically owing to the failure of the engineer to acknowledge a more restrictive signal, the train will stop because the brakes cannot be released until the reset switch is operated. The switch is so located that the engineer must descend to the ground in order to operate it. This circuit is taken from a tap *3* on the *A2* wire, Fig. 17, through one arm of the reset switch to wire *SP*, coil *SP1*, and wire *NA2* to wire *C* of the headlight generator. This circuit energizes all of the acknowledging relays, and completes the circuit from the headlight generator to the magnet

valve and permits him to release the brakes. The reset-switch circuit merely by-passes or short-circuits the pneumatic relay and the acknowledging switch.

When the relay *A* is deenergized, the magnet valve is deenergized owing to the circuit being established through the contact arms in their upper position. A circuit is now made at *A* and all acknowledging relays are picked up when the acknowledging switch is closed. Also, a stick circuit is made that energizes the relay *RP*. When the acknowledging switch is opened, the relays *SP* and *LP* drop; a stick circuit, however, keeps relay *RP* and the magnet valve energized.

When relay *R* drops its contact arms, the stick circuit is broken, and the magnet valve is deenergized. The acknowledging circuit then picks up all relays as before and thereby establishes a stick circuit that energizes relays *RP* and *LP*. When the acknowledging switch is open, the relay *SP* drops and the other two stay up. When relay *L* is deenergized, stick circuits through relays *LP* and *RP* are broken, and they drop their contact arms; this deenergizes the magnet valve again. Closing the acknowledging switch lifts all contacts as before, and establishes three stick circuits. Opening the acknowledging switch has no effect; all contacts stay up.

REVERSE OPERATION

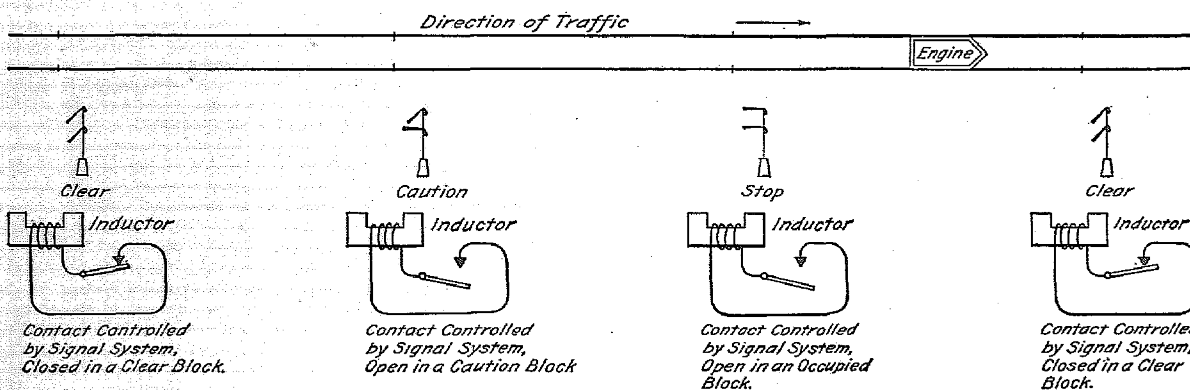
43. It should be noted that the track receiver must be ahead of any set of wheels; that is, between the set of wheels and the leaving end of the block in order to prevent the enforcement of the low-speed limit. Therefore, an engine running, tender forwards, in the direction of traffic or with a portion of the train in advance of the engine will be required to operate under the low-speed limit. This is also true if the engine is running forwards but in the reverse direction of traffic. Under either condition, the track receiver will be deprived of current by the first set of wheels, thereby causing the cab indication to change to a low light.

GENERAL RAILWAY SIGNAL COMPANY'S INTERMITTENT TRAIN CONTROL

WAYSIDE CIRCUITS AND SIGNAL CIRCUITS

44. Relation Between Circuits.—With intermittent train control, alternating current is not required in the rails to control the action of the engine equipment. The relation between the signal system and the wayside train-control equipment is shown in Fig. 18. An inductor is placed at the end of each block. This inductor is merely a bar of iron wound with a few turns of wire, known as a choke coil, so arranged that the ends of these wires may or may not, depending on conditions, be connected by a contact controlled by the signal system. In a clear block, the operation of the signal circuit is such as to close the contact as shown; in a caution or an occupied block the contacts are open. When the receiver on the locomotive passes an inductor with its contact closed, the locomotive equipment is not affected; however, when the contact is open the passage of a receiver over an inductor will result in the opening of a relay on the locomotive. The opening of this relay will result in the operation of the pneumatic equipment and in an application of the brake. Suitable means is provided to keep the relay closed, thus permitting an engine to pass over an inductor with its contact open without the brakes going on.

45. The receiver is merely an electromagnet magnetized by the current from the headlight generator and the inductor may be compared to the bar of an ordinary magnet. When the bar of an ordinary magnet is held close to the poles of its magnet, it is assumed that lines of force pass from the north pole of the magnet through the bar to the south pole and back through the magnet to the north pole. With the bar wound with wire and the ends not connected, if the bar is moved nearer to the magnet, the lines of force will increase at once. If the ends of the wire are joined and the bar is moved the same as before, the lines of force will increase the same amount as before but it will require longer time. It is this delay in the building up of the lines of force that permits the receiver to pass over an inductor



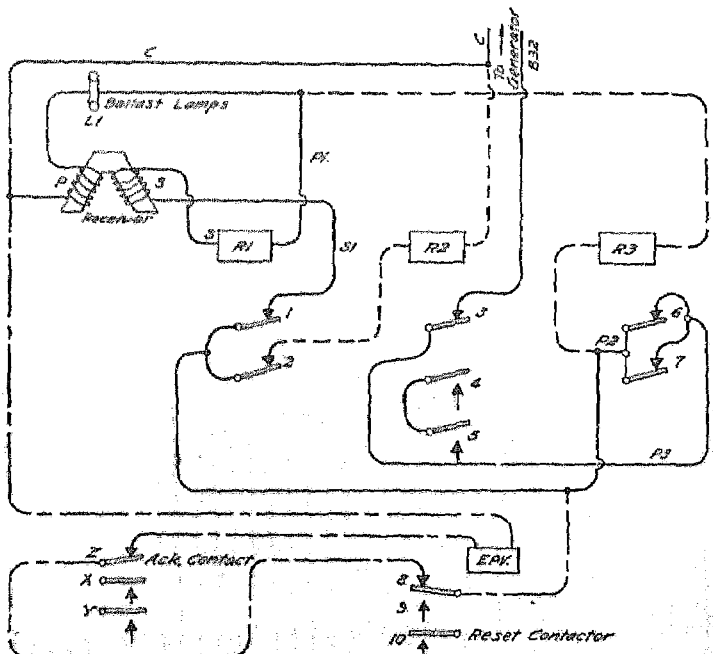
Wayside Circuits

FIG. 18

with the contact closed, without affecting the engine equipment. With the contact open, the building up of the lines of force occurs more rapidly, and the engine equipment is affected.

LOCOMOTIVE CIRCUITS

46. Normal Circuits.—In Fig. 19 is shown a diagram of the locomotive circuits with the engine between signals. Under this condition, all three relays *R1*, *R2*, and *R3* are energized from

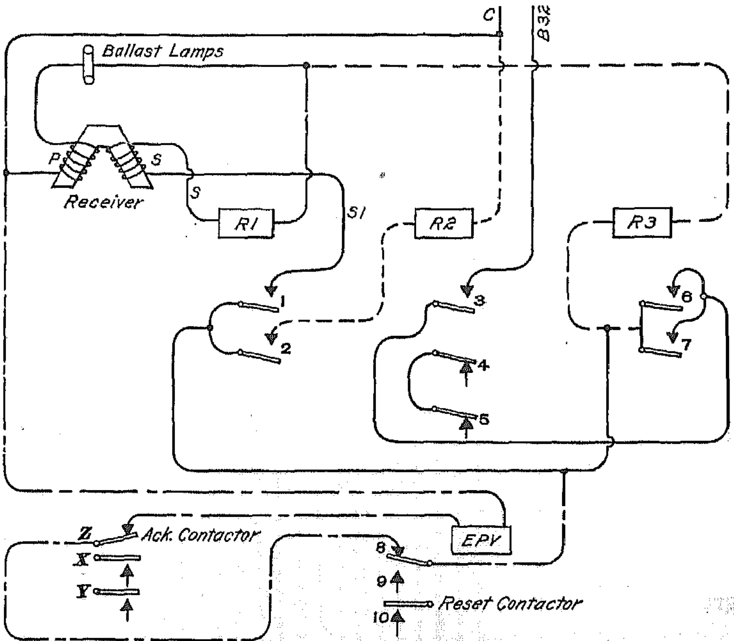


Normal Circuits

Fig. 19

the headlight generator; the electropneumatic valve is also energized. The circuit through this valve is completed from wire *B32* of the generator, through contact *3* of relay *R2*, wire *P3*, contacts *6* or *7* of relay *R3*, wire *P2*, contact *8* of the reset contactor, contact *Z* of the acknowledging contactor, and the electropneumatic valve *EPV* to wire *C* of the generator. Relay *R1* is energized through wire *B32*, contact *3*, wire *P3*, contacts *6*

or *7*, wire *P2*, contact *1*, wire *S1*, the secondary coil *S* of the receiver, relay coil *R1*, the ballast lamps, and primary coil *P* of the receiver to wire *C*. Relay *R2* is energized through wire *B32*, contact *3*, wire *P3*, contacts *6* or *7*, wire *P2*, contact *2*, and coil *R2* to wire *C*. Relay *R3* is energized through wire *B32*, contact *3*, wire *P3*, contacts *6* or *7*, wire *P2*, relay coil *R3*, the ballast lamps, and the primary coil *P* of the receiver to wire *C*.

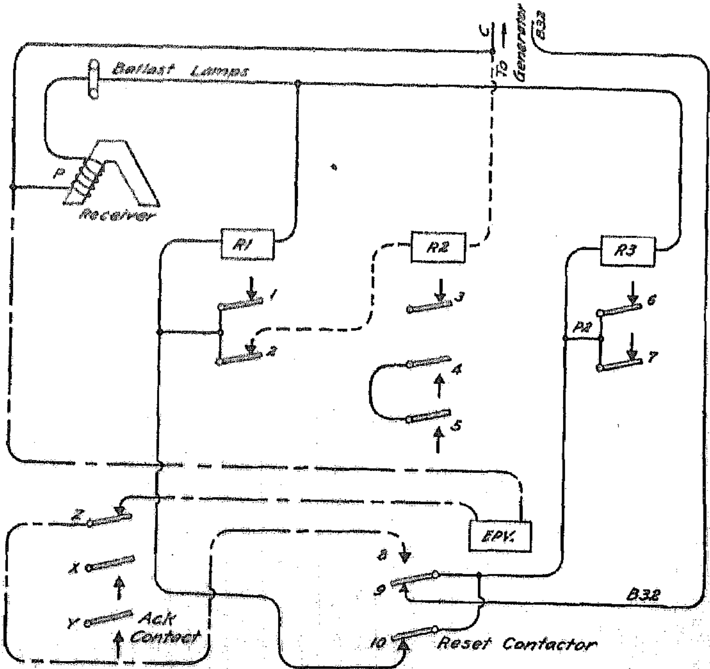


Circuits After passing open Inductor Unacknowledged

FIG. 20

47. Circuits After Passing Open Inductor Without Acknowledging.—In Fig. 20 is shown the circuits when the engine passes over an open inductor and the engineer fails to operate the acknowledging contactor. In this case an electromotive force momentarily induced in coil *S* is opposed to the electromotive force of the generator. This results in sufficient decrease in the current through the relay *R1* to cause the contacts *1* and *2* to open. It should be noted that the circuit of

relay *R1* was made through contact *1*, therefore this relay would not be reenergized after the inductor is passed. The relay *R2* is also deenergized when contact *2* opens; this in turn causes contact *3* to open and contacts *4* and *5* to close. The opening of contact *3* causes relay *R3* to be deenergized, and its contacts *6* and *7* will open; this results in the electropneumatic valve being deenergized. An application of the brakes will follow.



Reset Circuits
FIG. 21

48. Reset Circuit.—The reset contactor is so placed that it cannot be operated without the engineer descending to the ground, hence it can only be operated after the train stops. The purpose of the reset contactor is to establish a circuit that will restore all three relays to their normal position.

In Fig. 21, a circuit is completed through wire *B32*, contact *9* of the contactor, wire *P2*, relay *R3*, the ballast lamps, and the

primary coil *P* of the receiver to wire *C*. This circuit reenergizes relay *R3*, and causes contacts *6* and *7* to close. Another circuit is also made through wire *B32*, contacts *9* and *10*, coil of relay *R1*, the ballast lamps, the primary coil *P*, and wire *C*. This circuit reenergizes relay *R1* and closes contacts *1* and *2*. The relay *R2* is reenergized by a circuit through contact *10*, contact *2*, and the coil of relay *R2* to wire *C*. After all the relays are in their normal position, the reset contactor is returned to its normal position, thereby closing contact *8*. The electropneumatic valve is now energized through the contacts of relays *R2* and *R3* and contact *8*, as already explained.

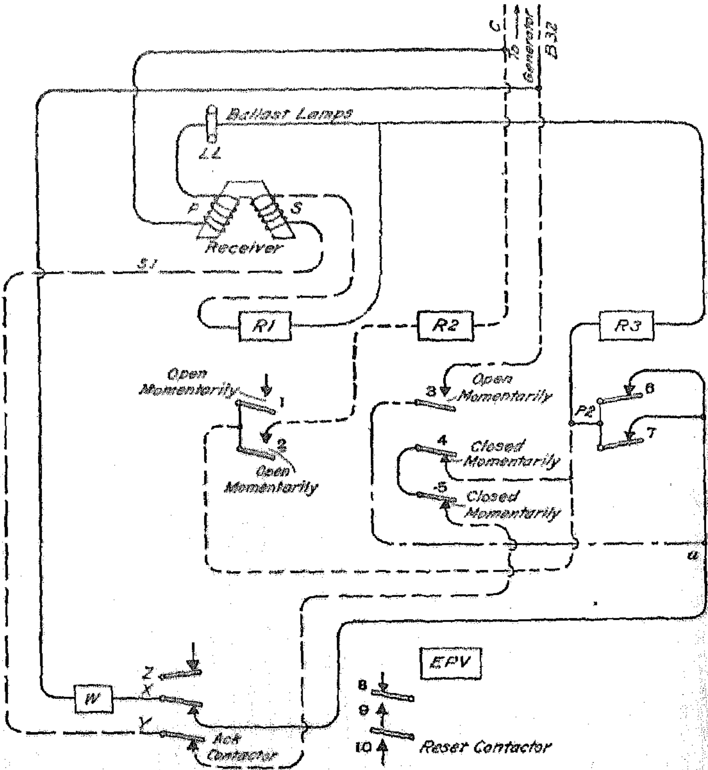
It should be noted that two operations are necessary to energize the electropneumatic valve: (1) the reset contactor must be placed in reset position so as to energize the relays; (2) the contactor must then be returned to normal position so as to permit the contacts of the relays to make a circuit through the electropneumatic valve. Hence, if the reset contactor is kept in reset position, the electropneumatic valve will not be energized.

49. Circuits When Passing Open Inductor, Acknowledging Contactor Closed.—In Fig. 22 is shown the locomotive circuits when the engine passes over an open inductor with the acknowledging contactor in acknowledging position as it should be. This position prevents the electropneumatic valve from being deenergized, hence the brakes will not be applied.

With the contacts *X* and *Y* of the acknowledging contactor closed, a circuit will be completed through wire *B32*, the whistle valve *W*, contact *X*, contact *6* or *7*, wire *P2*, coil of relay *R3*, ballast lamps, primary *P* of the receiver, and wire *C*. This forms a circuit through the coil of relay *R3* independent of the contacts of the other two relays as shown in Fig. 22. With the relay R3 energized, the electropneumatic valve will also be energized.

However, the circuit just described does not cause the whistle to blow, because the portion of the circuit including the whistle valve is short-circuited by the circuit shown by heavy dash-and-dot lines. This short circuit starts at the wire *B32* and passes through contact *3* back to the original circuit at *a*.

The action just explained occurs before the engine reaches the inductor; as soon as the receiver is over the inductor, the whistle will blow. The reason is as follows: With the receiver over the inductor, the contacts *1* and *2* of relay *R1* and the contacts *3*, *4*, and *5* of relay *R2* will drop, as already explained in



Circuits passing open Inductor Acknowledged

FIG. 21

Art. 47. With contact *3* open, the short circuit around the whistle valve is broken, therefore the whistle blows. When the receiver leaves the inductor the relay *R1* is energized by a current through wire *B32*, the whistle valve, contact *X*, contacts *6* or *7*, contacts *4* and *5*, contact *Y*, wire *S1*, secondary coil *S* of the receiver, coil of relay *R1*, the ballast lamps, primary coil *P*

of the receiver, and wire *C*. As soon as the relay *R1* picks up its contacts, relay *R2* will be energized and will in turn pick up its contacts *3*, *4*, and *5*. With the contact *3* picked up, the short circuit around the whistle valve is again completed and the whistle will stop blowing.

The acknowledging contactor must not be held closed for more than 15 seconds. If it is, the contact *Z* will be opened by a clockwork arrangement and the circuit to the electropneumatic valve will be broken.

UNION SWITCH AND SIGNAL COMPANY'S PNEUMATIC EQUIPMENTS

EQUIPMENTS FOR CONTINUOUS TRAIN CONTROL WITH ELECTRICAL ACKNOWLEDGEMENT

50. Parts of Equipment.—The pneumatic apparatus for a train-control equipment requires the addition of certain parts to the existing ET or AI locomotive brake equipments. These parts are so interconnected with these equipments that the brakes will be applied should the engineer neglect to act in accordance with the cab signal indications. The brake valve has been redesigned in order to retain all of the features of the H6 valve and also to secure the additional features necessary for the operation of the train control. The HS-2 brake valve, as it is called, is shown in Fig. 23, and contains a brake application valve, a cut-off valve, a vent valve, two rotary valves, and an equalizing piston.

Excluding the brake valve, the parts of the Union Switch and Signal Company's pneumatic equipment for an automatic stop comprises a governor magnet, a timing valve, and a split reduction valve. The split reduction valve (Fig. 24) may or may not be used, according to whether a continuous or a split reduction is desired.

51. The equipment for speed control comprises all of the parts mentioned and in addition a suppression valve and a reduction-insuring valve. These valves are necessary owing to the difference in the operation of an automatic-stop system and a speed-control system when entering a restrictive block. With

the former the operation of the equipment is suppressed by the acknowledging switch; a speed-control system is suppressed under the low-speed limit by the acknowledging switch, and above the low-speed limit by making a reduction of a specified amount. This latter action requires the use of a suppression

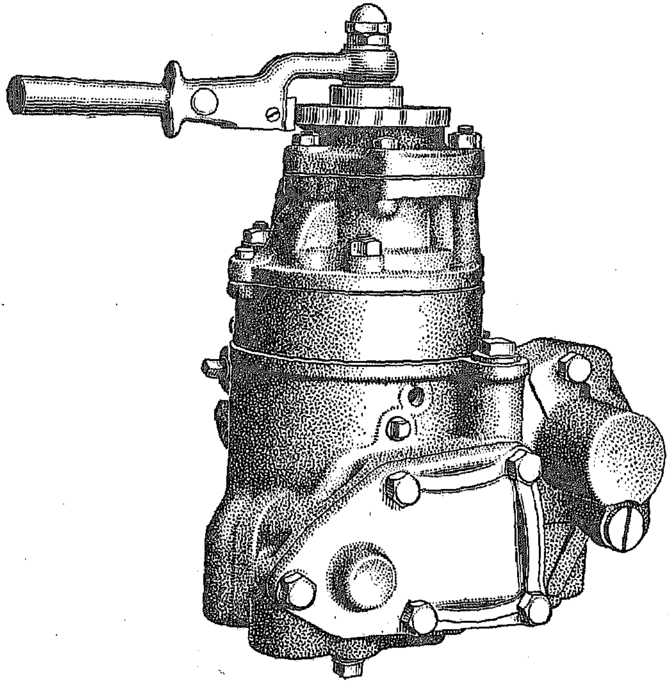


FIG. 23

valve and a reduction-insuring valve. These two valves, with the exception of the tension of their springs, are alike. See Fig. 25.

The purpose of the magnet valve when energized is to prevent the train control from cutting in by keeping the timing valve up, thereby causing the application valve to remain in normal position; also, when energized it permits the brakes to be released. Its purpose when deenergized is to cause the train control to cut in unless acknowledgement is made with an auto-

matic-stop equipment or the proper acknowledgement or suppression is made with a speed-control equipment.

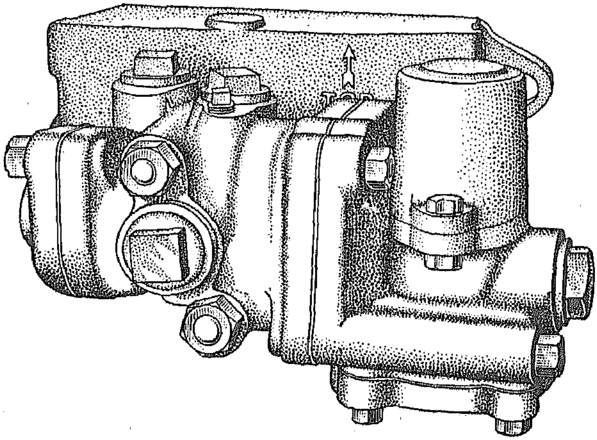


FIG. 24

The explanation of the pneumatic equipment will deal only with the action of the train-control apparatus. In this connection it will be necessary to assume that the engineer does not take the proper steps to prevent the train-control equipment from cutting in. However, it must be understood that the required action to prevent the operation of the train control must be taken in all cases; its operation indicates either neglect on the part of the engineer or his inability to operate the brakes, provided, of course, the equipment is in good condition. It is assumed that the reader is already familiar with the operation of the No. 6 ET locomotive brake equipment, and therefore understands the effect of each position of the brake valve on the operation of the distributing valve.

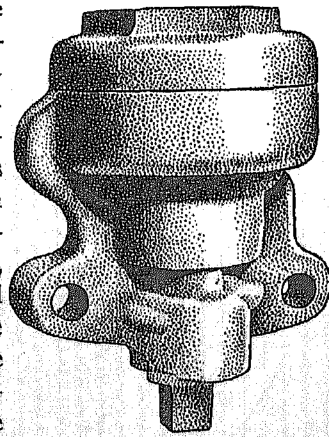


FIG. 25

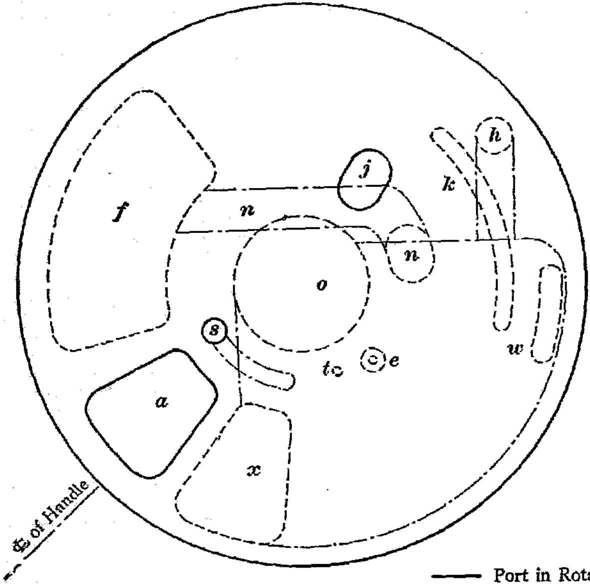


Fig. 26

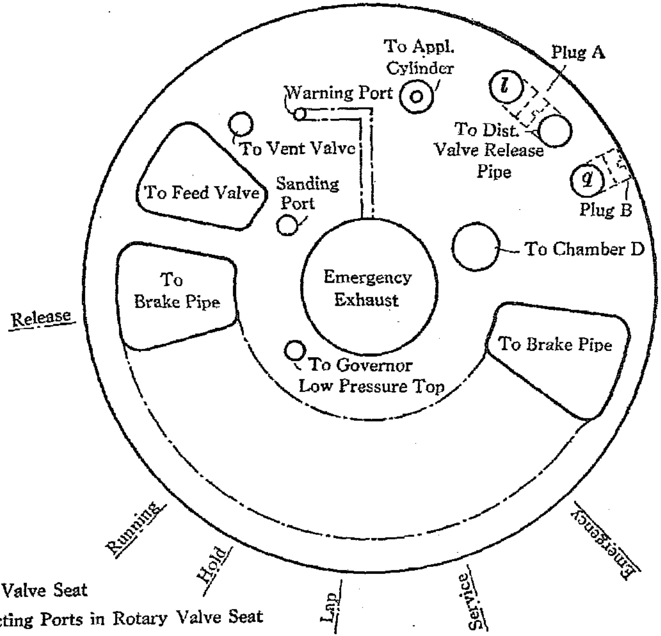


Fig. 27

—— Port in Rotary Valve Seat

—·— Passage Connecting Ports in Rotary Valve Seat

—— Port Through Rotary Valve

—·–· Port or Cavity in Interior of Rotary Valve

----- Port or Cavity in Face of Rotary Valve

Thus in full release position of the automatic brake valve, the brakes on the train are released and the locomotive brake is held applied. In running position, the locomotive brake is released; if desired to hold the locomotive brake applied longer than it is possible to keep the brake valve in full release position, then holding position is used instead of running position. In service position, the brakes are applied gradually; in emergency position the brakes are applied fully in a very short time. In lap position the brakes are held applied between service reductions.

52. Rotary Valves and Seats.—A view looking down through the lower rotary valve from the top is given in Fig. 26, and in Fig. 27 is shown a view of the lower rotary valve seat.

In full release position main-reservoir air passes through port *a* in the rotary valve to the port in the rotary valve seat that leads to the brake pipe; also, this air passes through port *j* in the rotary valve to the port in the seat that leads to chamber *D* and the equalizing reservoir. Main reservoir air passes through port *s* in the rotary valve to the governor in this as well as in running and holding positions, and the warning port is in communication with a port in the rotary valve seat that leads to the feed valve.

In running position, cavity *f* in the rotary valve connects the port in the rotary valve seat marked *to feed valve* to the port in the seat marked *to brake pipe*. Also, the air from the feed-valve port passes through passage *n* and port *n* in the rotary valve to the port in the rotary valve seat that leads to chamber *D*. The port in the seat that leads to the distributing-valve release pipe is connected through port and passage *h* in the rotary valve to the emergency exhaust.

Holding position is similar to running position, except that port *h* no longer connects with the port to the release pipe.

In service position, port *e* in the rotary valve registers with the port in the seat that leads to chamber *D*. Port *e* is restricted instead of the port in the seat as with other types of brake valves.

In emergency position, port *x* in the rotary valve registers with the port in the seat marked *to brake pipe* and the air is vented

to the emergency exhaust. Main-reservoir air passes through port *j* in the rotary valve to the sanding port, to the port in the seat that leads to the feed-valve port, and thence by way of the groove *k* to the ports in the seat that lead to the vent valve and to the application cylinder pipe. Chamber *D* and the equalizing reservoir vent to the emergency exhaust through port *t*.

If the reader wishes to verify the foregoing port connections, it is only necessary to trace Figs. 26 and 27 on tracing cloth and

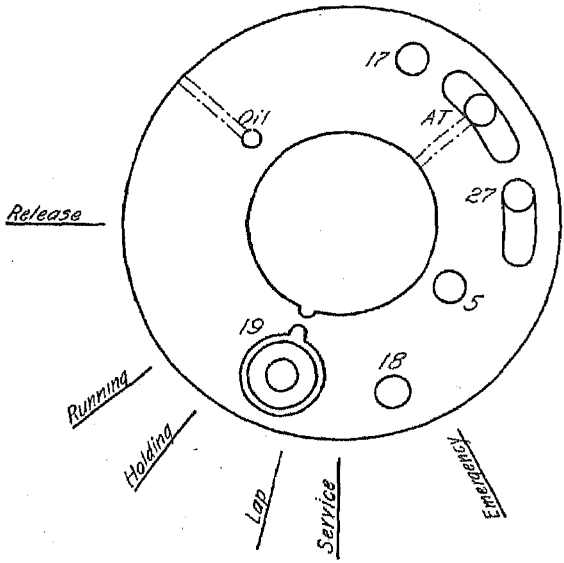


FIG. 28

then lay the rotary valve on its seat. The tracing of the rotary valve must not be turned upside down, because Fig. 26 is a top view.

53. In Fig. 28 is shown a view of the upper rotary valve seat as it would appear if the brake valve were viewed from the top with the ports marked to correspond to the diagrammatic views. The face of the upper rotary valve comes uppermost; hence, with the brake valve viewed from the top, the rotary valve will appear as in Fig. 29. The cavity *a* is filled with an oil-saturated wick.

In release position, cavity *d* in the rotary valve and passages *e* and *f* connect ports *5* and *27* to the exhaust port *AT*; also, cavity *c* connects port *27* to port *AT*.

In running position, cavity *b* connects ports *18* and *19*, cavity *d* and passages *e* and *f* connect ports *5* and *27* to port *AT*, cavity *c* connects port *17* to port *AT*.

In holding position the port connections are the same as in running position.

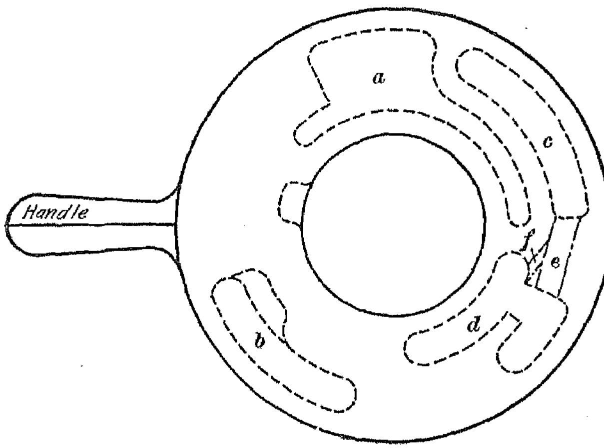


FIG. 29

In lap position, the square cavity in the rotary valve that leads into the central cavity of the valve, connects the small projection in the groove surrounding port *19* to a similar projection in the central cavity in the rotary valve seat. Should the rotary valve leak, the above connection insures that main-reservoir air does not leak into the suppression limiting port *19* in lap position. The air will pass, instead, around the rotary valve key, which has clearance, thence through the passage shown dotted to port *AT* and to the atmosphere. Any increase in the pressure in pipe *19* during a train-control suppression would reduce the amount of the reduction necessary to suppress permanently a train-control application.

In service position, cavity *b* connects port *18* to port *27*, and cavity *d* connects port *17* to the atmosphere.

In emergency position, cavity *b* connects ports *5* and *27* to port *AT*.

These port connections can be verified by tracing the rotary valve and then, without inverting it, place it on a tracing of the seat.

The port marked *oil* is drilled through to the outside periphery of the seat to allow main-reservoir air that is present around the periphery of the rotary valve seat to enter the oil cavity in the rotary valve in all positions and thus reduce friction to a minimum.

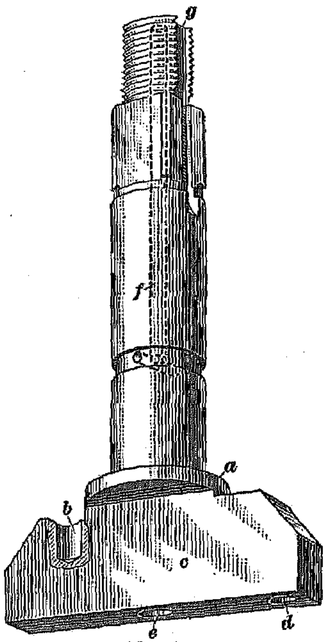


FIG. 30

The rotary valve key is shown in Fig. 30. The back of the upper rotary valve rests on the collar *a*, and a pin in this valve fits in the hole *b*, thereby insuring that the rotary valve is placed in its proper position on the key. The rectangular portion *c* rests between four wings on the lower rotary valve; a pin in the valve fits in the hole *d*. A spiral spring in the hole *e* holds the rotary valve to its seat; an oil hole is shown at *f*. A pin in the brake-valve handle in combination with the groove *g* prevents the handle from being applied to the rotary-valve key in the wrong position.

EQUIPMENT FOR AUTOMATIC STOP WITH CONTINUOUS LIMITED REDUCTION

54. Manual Operation.—In Fig. 31 is shown a diagrammatic view of the pneumatic equipment of an automatic-stop system of continuous train control. With the exception of the automatic brake valve, the other parts of the locomotive brake equipment are not shown. The equipment is shown in normal position with the magnet valve energized and the brake valve in

running position. With such a system, as already explained, the engineer must acknowledge the cab indication when it changes to a more restrictive condition, otherwise the brakes will be applied automatically.

Under ordinary conditions the HS-2 brake valve is operated in the same manner and performs the same functions as the H6 brake valve. Thus, the brakes on the locomotive and the train are applied by moving the handle of the brake valve to service position, and are held applied by going to lap position. The brakes on the train are released and the brake on the locomotive is held applied by going to release position, and the locomotive brake is released in running position.

The manual operation of the brake valve is in no way interfered with by the train-control apparatus; the various devices that make up this apparatus act independently of the brake valve when the change in cab indications is not properly observed.

55. Running Position.—In running position, air passes from the feed valve through pipe *9*, Fig. 31, thence by way of passage *18*, passage *a*, the cut-off valve, passage *13*, and the double-heading cock to the brake pipe. The air from the brake pipe passes through passage *13* and charges the chamber beneath the equalizing piston. From passage *18*, the air passes to passage *21*, thence by way of the slide valve *b* of the automatic application valve and passage *8* to the equalizing reservoir and chamber *D*. The air from passage *a* also passes through passage *18'* and thence by way of the slide valve *b* to passage *11*, and the outer end of the cut-off valve. The pressure in the spring chamber of the cut-off valve combined with the tension of the spring keeps the valve open as shown, thereby establishing communication between the feed-valve pipe and the brake pipe, as already explained. Air from the main reservoir passes through passage *MR* to chamber *6* of the automatic application valve and, feeding through the small port *c* in the application piston, charges pipe *10* and the top chamber in the timing valve. A pipe from the reducing valve of the independent brake valve conveys air at a pressure of 60 pounds to the magnet valve, which is now assumed to be energized. The air then passes by the

lower valve *d*, which is held down when the magnet valve is energized, up by the fluted body of the valve to passage *e*, and charges the timing reservoir. The air also passes under the piston of the timing valve and moves it to its upper position as shown. The lower valve *f* now closes the upper valve *g*, thereby breaking the communication between pipe *10*, and passage *h* and the atmosphere. The reduction-limiting reservoir is connected by way of pipe *37* and the slide valve *b* to the atmosphere; this reservoir is also connected through pipe *17* and the upper or train-control rotary valve to the atmosphere. The pneumatic relay is connected through pipe *25* to the atmosphere at *1*.

56. Automatic-Stop Application.—The magnet valve is deenergized when the cab indication changes to a more restrictive condition; the whistle on the magnet valve portion then begins to blow. The engineer has now about 6 seconds to complete the acknowledgment, thereby energizing the magnet valve again and preventing a train-control application, otherwise the brakes will be applied automatically.

After acknowledging, the engineer must next act promptly and reduce the speed of the train to a safe limit. If not, he becomes responsible for an accident, because the fact that the train is running at speed after passing a restrictive block indicates that he acknowledged and then failed to bring the train under control. It will here be assumed, however, that the engineer neglects to acknowledge. In this event he is required to lap the brake valve as soon as the train control cuts in. When the magnet valve is deenergized, the air pressure of 60 pounds and the spring shown moves the two valves *d* and *i*, Fig. 32, upwards. The valve *d* now cuts off the supply of air to the timing reservoir and timing valve; the stem of valve *i* is fluted and permits the air in the timing reservoir and beneath the timing-valve piston to pass through passages *e* and *j* to the whistle. It requires about 6 seconds for the pressure in the timing reservoir to reduce to 15 pounds; the spring then seats the piston in the timing valve; the upper valve *g* now opens and permits the air in pipe *10* to escape through passage *h* in the timing valve to the atmosphere.

With the pipe *10* open through passage *h*, the pressure in chamber *k* reduces, the main-reservoir pressure in chamber *6* then forces the piston to application position as shown. The air in the equalizing reservoir now passes through passage *8*, a cavity in the slide valve *b*, and a restricted port *m*, to pipe *37* and the reduction-limiting reservoir. With the brake valve lapped, the air cannot pass through pipe *17* to the atmosphere at the train-control rotary valve as would be the case if the brake valve were left in running position. The reduction-limiting reservoir is of such a size that the pressure in the equalizing reservoir will reduce about 22 pounds with a brake-pipe pressure of 70 pounds. The equalizing piston will rise as soon as the pressure begins to reduce in the equalizing reservoir, and the brake-pipe discharge valve will remain unseated until the reduction in brake-pipe pressure through passage *16* and the choke shown approximates the reduction in the equalizing-reservoir pressure.

57. The brake-pipe air in passage *BP*, Fig. 32, passes through a cavity in the slide valve *b* to pipe *25* and the pneumatic relay. This opens the relay and hence breaks the acknowledging circuit. With this circuit broken, the magnet valve, as explained farther on, cannot be energized and the brakes released until after the train has stopped. Therefore, the purpose of the pneumatic relay is to prevent acknowledgment that would defeat the proper action of the train-control equipment.

The spring chamber of the cut-off valve is connected through passage *11* to the atmosphere at the automatic-application valve. The cut-off valve is then moved to the position shown by the brake-pipe pressure in the interior of the valve and breaks the connection between the feed valve and the brake pipe so that the brakes cannot be released until the cut-off valve returns to normal position. This does not occur until after the train stops.

The restricted port *m* is of such a size that a reduction is made in the equalizing-reservoir pressure at the same rate as if a manual reduction was made. No mention has been made of the operation of the distributing valve in applying the locomotive brake; it is assumed that the reader is already familiar

with this phase of operation. The vent valve only operates when the brake valve is placed in emergency position. Then the main-reservoir air between the two rotary valves passes to the chamber in front of the large head of the vent-valve piston and moves it to the right. Brake-pipe air that is always on the spring side of the vent valve now escapes to the atmosphere at the exhaust port.

58. **Releasing After an Automatic Application.**—When the train stops, the engineer descends to the ground and operates the reset switch. As explained in Art. 42, this action reenergizes the magnet valve, and the valves *d* and *i*, Fig. 31, are moved down. The air now passes by the valve *d* to the timing reservoir and below the timing-valve piston; the piston is forced upwards, and the valve *g* closes. With this valve closed, the main-reservoir air in chamber *6* passes through the small port *c* in the application-valve piston to the pipe *10* until the pressures are about balanced on the piston, which is then returned to normal position by its spring. This action restores air to the outer end of the cut-off valve that will now be returned to normal position by its spring. When the brake valve is returned to release position, the brake pipe will recharge as already explained. The air in the reduction limiting reservoir is vented to the atmosphere through an exhaust port in the automatic application valve. The air in pipe *25* and the pneumatic relay also escapes through port *1*, when the automatic application valve returns to normal position.

Should the brake valve be left in running position when the train control cuts in, the air that enters the reduction-limiting reservoir will escape through pipe *17* to the atmosphere through the upper rotary valve and the top exhaust port of the brake valve. In this event the air in the equalizing reservoir will be completely vented; this will result in a complete venting of brake-pipe air.

The upper rotary valve insures that the train will be stopped should the brake valve be left in running position when the train-control equipment cuts in. In such an event, the equalizing reservoir will be connected to the atmosphere as already stated; also, the rotary valve will connect the spring chamber of the

automatic application valve to the atmosphere. This latter connection prevents the automatic application valve from moving to release position and releasing the brakes if for any reason the air in pipe *10* fails to vent at the timing valve.

The assumption is made that the reader is familiar with the action of the distributing valve in releasing the brake; hence, this phase of operation has not been explained. The distributing-valve release pipe is connected to the brake valve at *2* and the application cylinder pipe at *2'*.

EQUIPMENT FOR AUTOMATIC STOP WITH SPLIT REDUCTION

59. Automatic-Stop Application.—The only difference between the pneumatic equipment shown in Fig. 31 and the one shown in application position in Fig. 33 is that the latter has a split-reduction valve. Instead of the total reduction being made continuously as already explained, the split-reduction valve makes an initial reduction of about 8 pounds, which is followed at a proper interval by another reduction of about 16 pounds. Splitting the reductions in this manner prevents harsh slack action in the train and causes the stop to be made more smoothly than otherwise.

It will be assumed, as before, that the engineer fails to acknowledge a change of cab indications and permits the train-control equipment to operate.

When the train control cuts in, owing to the magnet valve being deenergized, this valve, the timing valve, the cut-off valve, and the automatic-application valve operate in the same manner as already described.

With the automatic-application valve in application position, the air from the equalizing reservoir and chamber *D*, Fig. 33, passes through passage *8*, a cavity in the slide valve, and the restricted port *m* to pipe *37* and the first reduction reservoir. This flow of air is the same as before, except that the air discharges to the first and then to the second reduction reservoir instead of to a reduction-limiting reservoir, which is therefore omitted.

The first reduction reservoir is of such a volume relative to the equalizing reservoir that, with the two connected, a reduction

of from 7 to 8 pounds, based on an initial brake-pipe pressure of 70 pounds will be made in the pressure in the equalizing reservoir and in chamber *D* of the brake valve. The equalizing piston then lifts and the brake-pipe pressure reduces an equal amount through the service exhaust choke fitting. This choke restricts the discharge of air from the brake pipe, and a back pressure is set up that results in some of the air flowing through pipe *16* to chamber *n* of the control piston of the split-reduction valve.

The brake-pipe back pressure in chamber *n* of the large piston overcomes the brake-pipe pressure in chamber *o* of the small piston, and the control piston and its slide valve move to the position shown. The air from the brake-pipe passage *BP* in the brake valve will now pass through the slide valve *b* of the brake-application valve to pipe *25* and the pneumatic relay, also through the slide valve of the control piston to the lock-up reservoir. Also, the air in pipe *1*, at a pressure of 60 pounds, passes by way of the slide valve to passage *40A*, thereby causing the hold-back piston *p* to move its slide valve to the position shown; in this position passage *40* is blanked and the connection between pipes *17* and *37*, and, hence, between the first and second reduction reservoirs is broken. The air in passage *40A* also charges the first timing reservoir through a restricted port and pipe *40*, but this reservoir only charges fully to 60 pounds with very long trains.

60. After the brake-pipe pressure has been reduced an amount about equal to the reduction that has been made in the equalizing reservoir, the equalizing piston moves down and seats the brake-pipe discharge valve; the further discharge of brake-pipe air then stops. The air in pipe *16* and chamber *n* will continue to escape at the restricted brake-pipe exhaust port until the pressure has fallen to about 30 pounds, then the control piston and its slide valve are returned to their normal positions, Fig. 34, by the brake-pipe pressure in chamber *o* acting on the small piston head.

With the control-piston slide valve in normal position, the air in chamber *r* and in the first timing reservoir begins to dis-

charge to the atmosphere through pipe *40*, passage *40A*, and the restricted orifice *AT'*. The holdback piston spring *s*, when compressed, has a tension of 15 pounds, hence, when the pressure in chamber *r* and the first timing reservoir reduces to about this amount, which requires from *7* to *17* seconds, depending on the pressure to which the timing reservoir was charged, the piston and its valve move back quickly to normal position as shown. The air in the timing reservoir and chamber *r* also vents through the upper port *AT* in the split-reduction valve.

The second reduction starts immediately because the normal position of the holdback slide valve connects pipe *37*, the first reduction reservoir, and the equalizing reservoir to pipe *17* and the second reduction reservoir, and again reduces the pressure in the equalizing reservoir and chamber *D*, thereby starting another reduction in brake-pipe pressure. The volume of the second reduction reservoir is such as to reduce the pressure in the equalizing reservoir an additional 15 or 16 pounds, thus making a total reduction of from 22 to 24 pounds from 70 pounds brake-pipe pressure. Correspondingly greater reductions will be had with higher brake-pipe pressures.

The air in the lock-up reservoir passes to chamber *t* and combining with the pressure in chamber *o*, holds the control piston in the position shown against the brake-pipe back pressure that passes again to pipe *16* and chamber *n*. The control piston therefore cannot move on the second reduction and break the connection between the first and second reduction reservoirs.

61. The time interval between the first discharge of air at the orifice *AT'* and the return of the hold-back piston depends on the extent that the first timing reservoir has been charged, and this in turn is dependent on the length of time the control piston has been held over by the pressure in chamber *n*. With long trains, the pressure will be retained in this chamber longer than with short trains, the time varying from *7* to *17* seconds, the latter time holding with very long trains, in which event the reservoir charges fully to *60* pounds. The interval between reductions is then equal to the time required to reduce the pressure in pipe *16* to 30 pounds after the brake-pipe exhaust valve

seats plus the time required to reduce the pressure in chamber *r* and the first timing reservoir to 15 pounds.

With the brake valve in running position, the equalizing reservoir and the first-reduction reservoir are connected by way of pipe *17* and the upper or the train-control rotary valve to the atmosphere. Therefore, unless the brake valve is lapped when the train control cuts in, the air in the equalizing reservoir will be completely vented, thereby draining the brake pipe.

62. **Releasing the Brakes.**—The same procedure must be taken to release the brakes as already explained.

EQUIPMENT FOR SPEED CONTROL WITH CONTINUOUS LIMITED REDUCTION

63. **Automatic Stop and Speed Control.**—With an automatic-stop system of train control, it is possible by acknowledging to continue at speed after entering a restrictive block. A speed-control equipment requires a specified brake-pipe reduction to be made when entering a restrictive block above the low-speed limit, otherwise the equipment will apply the brakes and prevent their release for 50 seconds to 1 minute. The suppression of the equipment by a brake-pipe reduction requires a suppression valve and a reduction-insuring valve. However, at speeds under the low-speed limit, the operation of a speed-control equipment can be prevented by acknowledging when the cab indication changes from a high to a low light.

64. **Charging.**—It is only necessary to consider the reduction-insuring valve and the suppression valve when taking up the charging of the speed-control equipment shown in Fig. 35. Otherwise, the equipment charges in the same manner as the one shown in Fig. 31. Chamber *a* of the reduction-insuring valve, Fig. 35, and the suppression reservoir charge from the feed valve through pipe *19*, a passage in the train control rotary valve, passage *18*, and pipe *9*; the spring chamber of this valve charges from the brake pipe through pipe *13*. Therefore, the piston *b*, owing to the spring pressure, remains in the position shown; the valve *c* now prevents the escape of air from the spring chamber, and the valve *d* has the timing reservoir, cham-

ber *e* of the suppression valve, and pipe *27* open to the atmosphere at the port *AT* in the reduction-insuring valve.

The spring chamber of the suppression valve and the pneumatic relay are open through pipe *25*, the slide valve of the automatic-application valve, and passage *1* to the atmosphere. The stop reservoir is connected through the open valve *f* of the suppression valve to pipe *5*, which in turn is connected to the atmosphere at the train-control rotary valve. Also, the stop reservoir is connected through pipe *5* to the atmosphere at the port *AT* in the timing valve.

65. **Automatic Speed-Control Application.**—In Fig. 36 are shown the positions the parts of a speed-control equipment assume when the proper steps have not been taken to prevent the equipment from operating. It is assumed that the engineer laps the brake valve at the time the application begins. The equipment shown is arranged for a continuous limited reduction.

When the magnet valve is deenergized, the timing valve, the automatic-application valve and the cut-off valve operate as already explained. That is, when the piston in the timing valve moves down, owing to the venting of the air from the timing reservoir to the whistle, the upper valve *g* in the timing valve unseats, thereby connecting chamber *h*, the supply reservoir, and pipe *10* through pipe *5* and by the unseated valve *f* in the suppression valve to the stop reservoir. The reduction that now occurs in the pressure in pipe *10* and chamber *h* causes the main reservoir pressure in chamber *6* to move the application-valve piston to service position as shown. With the slide valve in application position, the air in the equalizing reservoir passes through passage *8*, a cavity in the valve, and thence through a restricted port *m* to the reduction-limiting reservoir. This reservoir is of such a size as to reduce the pressure in the equalizing reservoir about 22 pounds; the pressure in the brake pipe then reduces an equal amount.

66. With the slide valve of the automatic application valve in application position, Fig. 36, the air in the spring chamber of the cut-off valve escapes, as before, through passage *11* to the atmosphere; the valve is closed by brake-pipe pressure on

the opposite side. The brake-pipe air in passage *BP* passes to the pneumatic relay and, its contacts open, the air also passes to the spring chamber of the suppression valve. With the acknowledging circuit broken by the pneumatic relay, the engineer is prevented from acknowledging until after the application valve returns to normal position.

The main-reservoir air in chamber *6* passes through the small port in the piston and charges the supply reservoir, pipes *10* and *5*, and the stop reservoir until the pressure in these places becomes nearly equal to the pressure in chamber *6*; the spring shown then forces the application-valve piston to normal position. This action is known as the kick-back and occurs in about 50 seconds to 1 minute after the train control cuts in if acknowledgment was not made during the 6 seconds delay time when above the low-speed limit. The kick-back will occur in 4 seconds after the low-speed limit is reached if acknowledgment was made during the 6 seconds delay time or between the time the magnet was deenergized until the automatic-application valve moved to application position. The air in pipe *25* now escapes through the port *AT* of the application valve, thereby causing the pneumatic relay to close its contacts; also, the cut-off valve opens owing to the admission of brake-pipe air to its spring chamber. By this time the train has stopped.

67. The reason why the kick-back occurs within 4 seconds after the low-speed limit is reached, provided acknowledgment was made during the 6 seconds delay time when above the low-speed limit is that, as soon as the magnet valve is energized, the timing valve operates and closes the upper valve *g*, Fig. 36. With pipe *10* cut off from the stop reservoir at the timing valve, this pipe, the supply reservoir, and chamber *h* will charge sufficiently in 4 seconds for the spring in the automatic-application valve to move the piston to release position.

The suppression valve and the reduction-insuring valve perform no particular functions during a speed-control application except the following: The brake-pipe pressure in pipe *25* and in the spring chamber of the suppression valve prevents any pressure that accumulates in chamber *e* above from moving the

suppression valve; this prevents undesired suppression of the equipment.

During a speed-control application some of the air that is exhausting from the brake pipe passes through pipes *16* and *27* to chamber *e* of the suppression valve. The air then passes by the open valve *d* of the reduction-insuring valve, here shown closed, to the atmosphere until a reduction of 10 pounds has been made in brake-pipe pressure; the valve *d* then moves to closed position. Brake-pipe air in pipe *25* also passes to the chamber of the suppression valve; the spring then holds the piston in the position shown, and prevents undesired suppression.

The brake-pipe pressure in pipe *13* and in the spring chamber of the reduction-insuring valve gradually decreases as the brake-pipe discharge continues, until the pressure trapped in pipe *19*, in the suppression reservoir, and in chamber *a* overcomes the air and spring pressures in the spring chamber. The piston *b* then moves forwards, and seats the valve *d* and unseats the valve *c*. The brake-pipe air in the spring chamber now passes by the valve *c* to pipe *27* and chamber *e* of the suppression valve. However, the combined air and spring pressures in the spring chamber of this valve prevent any movement of the piston. With the valve *d* closed, any air discharging from the brake pipe must now vent through the restricted choke at the brake valve.

68. The train is always stopped when the train-control equipment cuts in, except under the condition explained in the next paragraph. This is necessary because the fact that the equipment cuts in may imply that the engineer is incapable of operating the brakes.

Thus, if the engineer after having properly acknowledged the change from a high to a low light is running in a low-speed block below the low-speed limit, an increase in the speed above this limit will not cause the equipment to stop the train, provided the brake valve is lapped at once. A reduction will be made just sufficient to reduce the speed to the low-speed limit, the magnet valve will then be reenergized, the application valve will return to normal position, and the brakes can be released.

69. Releasing the Brakes.—It has already been explained that the automatic-application valve returns to normal position in about 1 minute after the train control cuts in. Also, it has been explained that this action causes the cut-off valve to open and also causes the pneumatic relay to close its contacts. Therefore, after a train has been stopped by a train-control application, the brakes can be released by first operating the acknowledging switch, thereby energizing the magnet valve, and then following the usual procedure with the brake valve. If acknowledgment was made before the train control cuts in, no further action is necessary to obtain a release after the automatic-application valve returns to normal position, except to operate the brake valve. If the cab indication changes from a low to a high light at any time, the magnet valve then becomes energized and it is unnecessary to acknowledge before releasing.

It will be noted that, with the cut-off valve open, the air from the main reservoir is free to pass to the brake pipe when the brake valve is placed in full-release position.

With the acknowledgment already made, the magnet valve will be automatically energized as soon as the speed has reduced to the low-speed limit. The engineer will be advised when the magnet valve is energized, by a short blast of the whistle and a quick return of the hand of the train-control gauge to 60 pounds. It will be remembered that, with the acknowledgment already made, the contacts of the acknowledging relay were picked up before the circuit was broken by the pneumatic relay.

If acknowledgment was not made before the train control cuts in, then the acknowledging circuit cannot be completed by operating the acknowledging switch until the kick-back has exhausted the air from the pneumatic relay; also, the low-speed switch at the axle governor must be closed.

If an attempt is made to release the brakes before the magnet valve is energized, pipe *5*, Fig. 36, will be opened to the atmosphere at the brake valve, thereby reducing the pressure in pipe *10* and causing the train control to cut in again. Therefore, the magnet valve must always be energized before an attempt is made to release the brakes, otherwise the train-control equipment will again operate.

70. Suppressing the Train-Control Equipment.—At speeds above the low-speed limit, the operation of a speed-control equipment can be suppressed on a change from a high to a low light by making a brake-pipe reduction of a certain specified amount. This phase of operation requires the use of two valves, a suppression valve and a reduction-insuring valve. At speeds under the low-speed limit it is only necessary to operate the acknowledging switch to prevent the device from operating when the cab indication changes to caution; this action reenergizes the magnet valve.

The term *forestalling* is used when the operation of the equipment is prevented by the acknowledging switch; the term *suppression* is used when the equipment is prevented from operating by a brake-pipe reduction.

The purpose of the suppression valve is to break the connection between pipe *5*, Fig. 37, and the stop reservoir, thereby preventing the train control from cutting in when making a manual suppression. The purpose of the reduction-insuring valve is to open the connection between pipe *5* and the stop reservoir unless a specified reduction has been made in brake-pipe pressure.

71. A brake-pipe reduction of from 10 to 12 pounds is required to suppress the operation of the train-control equipment, and this reduction must be started within 6 seconds after the whistle begins to blow. The timing-valve piston seats in 6 seconds after the whistle starts blowing and the train control cuts in.

When the cab indication changes from green to orange or from high to low, the governor-magnet valve and the timing valve operate as already explained, and the air in pipe *10*, Fig. 37, passes to pipe *5* and thence for the instant by way of the unseated valve *f* in the suppression valve to the stop reservoir. With the brake valve in service position the equalizing reservoir and chamber *D* are connected through passage *8*, slide valve *b*, passage *21*, and the rotary valve to the atmosphere at *AT*. However, the automatic brake application valve does not now operate as with a speed-control application. The reason is as follows: The air admitted from the brake pipe by way of the double-heading cock,

the cut-off valve, passage *18*, the upper rotary valve, and pipe *27* to chamber *e* in the suppression valve, and from the brake-pipe exhaust through pipes *16* and *27* to chamber *e*, deflects the diaphragm *j* against the tension of the 20-pound spring and closes the valve *f*. With the flow of air from pipe *5* to the stop reservoir interrupted at valve *f*, the air in the supply reservoir will compensate for the drop in pressure that occurs in pipe *10* when it vents to pipe *5*, hence the piston of the brake-application valve will not move. The air in pipe *27* passes slowly through the $\frac{3}{64}$-inch choke tee, then past the open valve *d* of the reduction-insuring valve, here shown closed, to the exhaust port *AT*. This discharge continues until the brake-pipe pressure in pipe *13* and in the spring chamber of the reduction-insuring valve reduces 10 or 12 pounds, then the air at brake-pipe pressure trapped in pipe *19* and the suppression reservoir will cause the piston *b* to close the valve *d*. The air in pipe *13* now passes by the valve *c* to pipe *27* and chamber *e*, thereby insuring that the valve *f* in the suppression valve is held closed.

72. The foregoing shows that the device is suppressed by cutting off the stop reservoir from pipe *5* at the suppression valve. The valve *f*, Fig. 37, must be closed about the time the timing valve seats, otherwise the pressure in pipe *10* will be reduced enough to allow the brake-application piston to move. The timing piston seats within 6 seconds after the air begins to discharge at the whistle, hence the application of the brakes must be started within this time interval in order to suppress the device.

The passage of air from the equalizing reservoir to the atmosphere and from the brake pipe to the brake-pipe exhaust port during a suppression is similar to the passage of air in other types of brake valves, such as the H6 and G6, and requires no explanation.

Proper acknowledgment should be made while the speed is above the low-speed limit; the low-speed circuit will then be complete, except at the axle governor. The circuit will close here when the speed reduces to the low-speed limit, the governor magnet then energizes, and the brake valve can be moved to

release position without reducing the pressure in pipes *10* and *5* and causing the train control to cut in.

Although it is not necessary to make acknowledgment while the speed is above the low-speed limit, it is desirable, because the engineer will be notified by a short blast of the audible signal and a quick return of the train-control gauge when the magnet is energized by the speed reducing to the low-speed limit.

The acknowledgment can be made at any time but it must be made before going to release position to prevent the train control from cutting in.

73. Insufficient Reduction to Prevent Suppression.—If an insufficient brake-pipe reduction, or one less than 10 or 12 pounds, is made, the operation of the train control cannot be suppressed and it will operate automatically.

When the brake valve is placed in service position, air from the brake pipe passes through pipe *27* to chamber *e*, Fig. 37, of the suppression valve, as already described; the air exhausting from the brake pipe also passes through pipe *16* and the check valve to pipe *27*. The valve *f* will then close as before and break the connection between pipe *5* and the stop reservoir. Pipe *27*, however, is still open to the atmosphere at the exhaust port *AT* of the reduction-insuring valve through valve *d*, and to get this valve closed requires a reduction of over 10 pounds in the brake-pipe pressure in pipe *13* and in the spring chamber of the valve. The spring has a tension of 10 pounds, so, unless a slightly greater reduction than this amount is made in the brake pipe, the brake-pipe pressure trapped in the suppression reservoir and chamber *a* above the diaphragm in the reduction-insuring valve cannot close the valve *d*. The valve then remains open with reductions under 10 or 12 pounds, and when the brake valve is lapped the air in pipe *27* will continue to escape at the exhaust port of the reduction-insuring valve. Finally, the pressure in chamber *e* will become so low that the spring in the suppression valve will move the piston back and out of contact with the valve *k*; the valve *f* is then unseated by the spring and stop *h*. The air in pipe *5* then passes to the stop reservoir, thereby causing the brake-application valve to move to application position.

EQUIPMENT FOR SPEED CONTROL WITH SPLIT REDUCTION

74. Operation.—In Fig. 38 is shown a diagrammatic view of the pneumatic equipment of a speed-control system with the split-reduction feature. With this exception, the operation of the equipment is similar to that shown in Fig. 37.

An extended explanation of the operation of this equipment is unnecessary. Its operation when the train control cuts in is identical with that of the automatic-stop equipment shown in Fig. 33.

When suppressing the operation of the equipment, the action that occurs is similar to that of the equipment shown in Fig. 37.

75. Cutting-Out Equipment.—All of the equipments described in the foregoing are cut out by breaking a seal and turning the handle of the cut-out cock at the application valve to closed position. This operation prevents the venting of air from the spring chamber of the application-valve piston, hence a train control application is prevented.

PURPOSE OF THE RESERVOIRS

76. Stop Reservoir.—The purpose of the stop reservoir is to delay the return of the brake-application valve to normal position during a train-control application until the reservoir charges to about main-reservoir pressure through the $\frac{3}{64}$-inch orifice in the brake-application piston. It requires from 50 seconds to 1 minute for the reservoir to charge and this gives the train control sufficient time to make a full service application of the brakes. The reservoir has a capacity of 800 cubic inches.

77. Suppression Reservoir.—The purpose of the suppression reservoir is to add volume to pipe *19*, Fig. 38, and the space above the diagram in the reduction-insuring valve, thereby insuring a permanent suppression by overcoming any leakage. The reservoir has a capacity of 525 cubic inches.

78. Supply Reservoir.—The purpose of the supply reservoir is to add volume to pipe *10*, Fig. 38, and thereby prevent a train-control application when pipe *10* vents into pipe *5* at the timing valve during suppression. The supply reservoir com-

pensates for this sudden reduction in pressure in pipe *10* and therefore prevents the brake-application valve from moving to application position. The supply reservoir has a capacity of 90 cubic inches.

79. Blowdown Timing Reservoir.—The air in the blowdown timing reservoir blows the whistle; also, it delays the timing valve from moving down until about 6 seconds after the magnet valve is deenergized. This gives the enginemen time to take the proper action to prevent a train-control application. This reservoir is located in the casting of the timing-valve bracket.

80. First and Second Reduction Reservoirs.—The purpose of the first and second reduction reservoirs is to limit the amount of the reduction made during a train-control application. The first reduction reservoir has a capacity of 65 cubic inches and equalizes with the equalizing reservoir when an 8-pound reduction is made in the latter.

The second reduction reservoir has a capacity of 300 cubic inches and equalizes with the equalizing reservoir and the first reduction reservoir when a further reduction of 14 pounds is made in the equalizing reservoir. These figures are from an equalizing-reservoir pressure of 70 pounds and will be proportionately higher with higher pressures.

81. Split-Reduction Timing Reservoir.—The purpose of the split-reduction timing reservoir is to provide, in conjunction with the split-reduction valve, the time interval between the first and second reductions during a train-control application of the brakes. This interval varies between 7 and 17 seconds and is governed by the degree of pressure to which the reservoir has been charged during the first reduction and the size of the restricted exhaust port through which the pressure must pass to the atmosphere. The reservoir has a volume of 325 cubic inches.

82. Lock-Up Reservoir.—The purpose of the lock-up reservoir is to lock the control piston in normal position when it returns to this position after the first reduction. The air in the lock-up reservoir passes to the space between the two heads

of the control piston and, assisted by the brake-pipe pressure on the opposite side of the small head, prevents the control piston from being moved by the brake-pipe exhaust pressure on the face of the large head during the second reduction. The reservoir is in the split-reduction valve bracket.

83. Timing Reservoir.—The timing reservoir adds volume to pipe *27*, Fig. 38, and thereby permits the 10- or 12-pound reduction required to secure suppression to be split into two reductions if so desired.

If it were not for the air in this reservoir the suppression valve would open pipe *5* to the stop reservoir immediately as the brake valve was lapped after the first reduction, and the train control would cut in. The air in the reservoir delays the action of the train control for a few seconds after the brake-pipe exhaust of the first reduction ceases, thus giving time to start the second reduction.

It must be remembered that pipe *27*, the timing reservoir, and the diaphragm chamber of the suppression valve are open to the atmosphere at the reduction-insuring valve until a 10- or 12-pound reduction has been made. Therefore, even with long trains the interval between the reductions must not be delayed too long if a train-control application is to be avoided.

PURPOSE OF THE CHECK-VALVES

84. Ball Check-Valve in Pipe 5.—Reference should be made to Fig. 38 when the purpose of the check-valves is being studied. The purpose of the $\frac{3}{8}$-inch ball check-valve *a* in pipe *5* is to permit a quick recharge of pipe *10* when the magnet valve is energized. When the magnet valve energizes, the timing valve moves up and cuts off pipe *10* from pipe *5* and connects pipe *5* and the stop reservoir to the atmosphere. The pipe *10* will charge in about 4 seconds after the magnet valve energizes, and the application valve will then return to normal position. Prior to the return of the valve, pipe *10* was in communication with pipe *5* at the slide-valve seat of the brake-application valve. At such time the ball check-valve prevents the air in pipe *10* from passing through pipe *5* to the atmosphere at the timing

valve, thereby preventing the return of the brake-application valve.

85. Ball Check-Valve Between Pipes 16 and 27.—The purpose of the $\frac{3}{8}$-inch ball check-valve *b* between pipes *16* and *27* is to prevent the air in the pipe *27*, with the brake valve in service position, from passing into pipe *16* and out the brake-pipe exhaust port. This condition would exist when making a suppression. The pressure in pipe *27* then builds up quickly on the suppression-valve diaphragm, thereby seating the lower check-valve and cutting off pipe *5* from the stop reservoir.

86. Check-Valve in Timing-Reservoir Pipe.—The purpose of the $\frac{3}{8}$-inch check-valve *c* with a $\frac{3}{64}$-inch choke in the timing-reservoir pipe is to limit the amount of air that will pass to the reservoir during the first reduction when a manual suppression is made with a split reduction. With the charging of the reservoir restricted, the time interval between the first reduction and the time the train control cuts in will be reduced; too long an interval would be undesirable.

The time interval between reductions is governed by the rate at which air escapes from pipe *27*, which is open to the atmosphere at the reduction-insuring valve until a 10- or 12-pound reduction has been made in brake-pipe pressure.

If the check-valve were omitted, the timing reservoir would charge too high during the first reduction; this in turn would permit the engineer to leave his brake valve in lap position for a longer period of time than otherwise before starting the second reduction of the suppression. A train at high speed will run a considerable distance in a short time and for this reason a delay of more than a few seconds in lap position is not desired. It will be noted that most of the air that enters the timing reservoir comes from the brake-pipe exhaust through pipe *16*.

87. Check-Valve in Pipe 25.—The purpose of the $\frac{3}{8}$-inch check-valve *d* with a $\frac{1}{32}$-inch choke in pipe *25* is to restrict the passage of air into this pipe from the spring chamber of the suppression valve when the brake-application valve returns to normal position. The air in pipe *25* above the check-valve now

passes quickly to the atmosphere at the No. *1* exhaust port of the brake valve, thereby permitting the pneumatic relay to close and acknowledgment to be made.

The following condition would exist were the check-valve omitted: The pipe *27* is connected to the brake-pipe pressure in pipe *13* by way of the upper check-valve in the reduction-insuring valve. This pressure in the spring chamber of the suppression valve will result in its upper check-valve being opened. The air in the stop reservoir, instead of going to pipe *5*, will pass instead to the spring chamber of the suppression valve and to pipe *25*, thereby holding the pneumatic relay open indefinitely and preventing acknowledgment from being made.

It will be noted that, with the magnet valve energized, the air in pipe *27* escapes to the atmosphere at the automatic-brake valve, and the air in the stop reservoir escapes at the brake valve and at the exhaust port of the timing valve. This only leaves the small volume of air in the spring chamber of the suppression valve to pass the check valve to pipe *25*.

88. Choke Tee in Pipe 27.—The purpose of the $\frac{3}{64}$-inch choke tee *e* in pipe *27* is to restrict the flow of air from this pipe to the timing reservoir and to the atmosphere at the reduction-insuring valve when making a suppression. This permits the pressure to build up quickly on the diaphragm of the suppression valve and results in pipe *5* being cut off from the stop reservoir.

The air that passes to pipe *27* is supplied from the brake pipe when the brake valve is placed in service position.

89. Ball-Check *f*.—The purpose of the ball check *f* is to prevent the air in pipe *25* from passing to the lock-up reservoir and the chamber between the heads of the control piston at the time the train control cuts in. The admission of air at this time would prevent the control piston from being moved to application position by the air in pipe *16*.

The air in the lock-up reservoir lifts the ball check and escapes through pipe *25* when the brake-application valve returns to normal position after a train-control application.

90. Ball-Check *g*.—The purpose of ball check *g* is to prevent the air that passes from pipe *1* to pipe *40* from passing quickly to the atmosphere at the slide-valve chamber of the hold-back piston, thereby allowing the pressure to build up immediately in the chamber below the hold-back piston, forcing it up. The air in the split-reduction timing reservoir lifts this check and escapes through passage *40A* when the control piston returns to normal position.

The choke *h* determines the degree to which the first timing reservoir charges during the first reduction when the train control cuts in. The time interval between the reductions depends largely on the extent that the reservoir charges.

The ball check in the passage to the equalizing reservoir is not used with the collapsible type of equalizing piston; the check is used only when the piston is of the solid type.

91. Dead-Engine Cock.—When in dead-engine position, the dead-engine cock permits air from the brake pipe to pass through the strainer and check-valve and charge the main reservoir. This provides main-reservoir pressure for the operation of the locomotive brakes and also such auxiliary devices as the bell ringer, etc.

BROKEN PIPES

92. Pipe 1.—Reference should be made to Fig. 38 when studying the effect of broken pipes. Should pipe *1* break, a train-control application will occur. If the pipe breaks at the timing valve, plug the pipe and cut out the train-control equipment by turning the handle of the cut-out cock at the automatic brake application valve to closed position.

If the pipe breaks at the split-reduction valve, plug the pipe and proceed. A split reduction will not then be obtained during a train-control application.

93. Pipe 5.—The fact that pipe *5* is broken or leaking badly will only cause trouble when the train-control equipment is permitted to cut in; there is no air pressure in this pipe at any other time. Then when on a low light, cut out the train control in order to release the brakes; when the light changes to high,

cut the train control in again. Thereafter acknowledge and pass all caution signals at a speed of less than 20 miles per hour.

94. **Pipe 10.**—A train-control application will occur when pipe *10* breaks. With this pipe broken, cut out the train-control equipment.

95. **Pipes 13 and BP.**—Pipes *13* and *BP* contain brake-pipe air and should they break off or leak badly, plug the ends toward the flow of air and cut out the train-control equipment.

96. **Pipe 19.**—Should pipe *19* break off, plug the pipe toward the flow of air, and, as this break prevents suppression, pass caution signals at a speed of less than 20 miles an hour.

97. **Pipes 16 and 27.**—Either pipe *16* or *27* when broken off will affect the operation of the train-control equipment when an attempt is made to suppress on a change from a high to a low light. Under such a condition, lap the brake valve and wait for the kick-back, then acknowledge and release the brakes. Thereafter pass all caution signals at a speed less than 20 miles an hour.

98. **Pipe 37.**—A failure of pipe *37* will have no bad effect unless the train-control equipment is permitted to cut in. A split-reduction will not then occur, also the brake-pipe exhaust will continue to blow until the kick-back takes place. Acknowledgment should then be made and the brakes released.

99. **Pipe 17.**—When pipe *17* breaks off and the train-control equipment is permitted to cut in, the brake-pipe exhaust on the second reduction will continue to blow until the kick-back occurs. Acknowledgment should then be made and the brakes released.

EQUIPMENT FOR SPEED CONTROL WITH PNEUMATIC ACKNOWLEDGEMENT

100. **Charging.**—In Fig. 39 is shown a diagrammatic view of a two-speed train-control equipment with the pneumatic acknowledgment feature. The equipment is assumed to be in normal position, with the magnet valve energized, and the brake valve in running position.

Air from the main reservoir passes through the dirt collector to passage *2* in the brake-application valve and charges chamber *A*; also, the air passes through passage *b* and the slide valve of the application pilot piston to chamber *B* at the outer end of the piston. From chamber *A* the air flows through passage and pipe *6* and charges chamber *C* between the two rotary valves in the brake valve. A branch from pipe *6* conducts the air to the brake-pipe feed valve; the air then flows through the lower rotary valve, pipe *3*, and the double heading cock to the brake pipe. A branch pipe *3* from the brake-pipe conveys brake-pipe air to the chamber beneath the equalizing piston *15* and to the spring chamber of the reduction-insuring valve. Also, air passes from passage *3* at the brake valve to a passage *19*, thence through the upper rotary valve and pipe *19* to the diaphragm chamber *D* of the reduction-insuring valve and the suppression-limiting reservoir. The brake-pipe air in passage *19* at the brake valve passes through passage and pipe *21*, the application slide valve and pipe *8*, and charges the equalizing reservoir.

101. The main-reservoir pipe *2*, Fig. 39, conveys air to the train-control feed valve, where the pressure is reduced to 70 pounds. From the feed valve, the air passes through pipe and passage *1* to chamber *E* of the pilot-valve piston. The air from pipe *1* also passes through the cut-out cock to chamber *F* in the relay portion, thence through passage *c* and the timing valve *d* to chamber *G*. At the point *e* near the magnet valve, the air leaves pipe *1* and passes through passage *e*, the strainer, the lower end of valve *f* and passage *g*, and charges the blow-down reservoir and chamber *15*. At one end, passage and pipe *4* is charged with pipe *1* pressure from chamber *E*; this passage and pipe at the other end charge with pipe *1* pressure from chamber *F*. From chamber *E*, the air passes through a port in the pilot piston to passage *4*, thence by way of the upper valve *h* in the reduction suppression valve to pipe *4* and passage *4* in the relay portion. The pipe *1* air in chamber *F* also charges passage and pipe *4*, through passage *i*, and the choke *j*. The quick-release reservoir charges to the pressure in pipe *1* through passage and pipe *18* that connects to passage *4*.

The timing reservoir No. *2* and chamber *H* in the reduction suppression valve are connected through pipe *27* to the atmosphere by the upper rotary valve. The timing reservoir No. *1* is connected through passage *25* to the atmosphere at the reduction hold-back valve. The first reduction reservoir is connected through passage *17* to the atmosphere through the slide valve of the application piston; the second reduction reservoir is connected through pipe *17* to the atmosphere through the upper rotary valve of the brake valve. The stop reservoir is open to the atmosphere through the relay or low-speed slide valve.

102. Automatic Train-Control Application, Speed Over 20 Miles per Hour.—When the magnet valve is deenergized by a change from a high to a low light the valve *f* is moved upwards by its spring and an air pressure of 70 pounds to the position shown in Fig. 40. The supply of air from pipe *1* to the blow-down reservoir and chamber *15* is now cut off by the seating of the lower valve of the valve *f* and the air in this reservoir and chamber is vented by way of the upper valve and passage *13* to the atmosphere at the blow-down valve, this valve being operated by the movement of the main governor. The blow-down valve is so designed that the opening through it is proportional to the speed, the higher the speed the larger the opening. If the speed is 20 miles per hour or less, the delay time before the timing valve *d* and its piston operate will be about 40 seconds and will be gradually shortened for higher speeds. At 50 miles per hour the delay time will be about 6 seconds.

The air in the blow-down reservoir, in passage *15*, and chamber *15* will eventually pass to the atmosphere until the pressure is reduced to about 40 pounds when the spring will move the timing piston to the right and deflect the diaphragm; the timing valve *d* will then be moved in the same direction by its spring. The air in chamber *G* now passes by the right end of the timing valve to the atmosphere; the left end of the valve seats and prevents the escape of air from passages *1* and *c*. The pressure in chamber *F* below the relay slide-valve piston forces it upwards, and the relay or low-speed slide valve then vents the air in pipe *4*

through passage *14* to the stop reservoir; therefore, the pressure in this pipe back as far as the spring chamber of the pilot piston is considerably reduced. The movement of the low-speed slide valve also connects pipe *4* and chamber *E* by way of passage *9* to the low-speed governor valve, which is always open at speeds above 20 miles per hour.

103. The venting of the air in pipe *4*, Fig. 40, to the stop reservoir and to the atmosphere at the low-speed governor if the speed is above 20 miles per hour, reduces the pressure in pipe *4* faster than it is being supplied from pipe *1* through the small port in the pilot piston and the choke *j* in the relay portion; the piston and slide valve then move to the right. In this position of the slide valve, the pressure in chamber *B* above the application piston is vented to the atmosphere; the pressure in chamber *A* below the piston moves it and the slide valve upwards, the latter then making the following connections: Pipe *6* is connected to pipe *3*; this removes the main-reservoir pressure from the chamber *C* between the rotary valves in the brake valves and connects this chamber to the brake-pipe pressure in pipe *3*.

Passage *17* is connected to passage *8*; this connects the equalizing reservoir to the first reduction reservoir, and to the spring chamber of the reduction hold-back valve, also to the annular space *k* around the top of this valve.

It will now be explained how the automatic train-control application is made in the form of a split reduction. The capacity of the first reduction reservoir is such that the air in the equalizing reservoir when vented to it, will reduce 8 pounds from a pressure of 70 pounds. When the equalizing piston lifts in response to the reduction in the equalizing reservoir, the brake-pipe pressure in the chamber below the piston passes through passage *18* to the chamber above the reduction timing valve piston and forces it down. The brake-pipe air now passes through passage *l* to the atmosphere, also the air lifts the ball check *25* and passes through passage *25* to the No. *1* timing reservoir; in addition the air passes from passage *25* to the chamber below the diaphragm of the reduction safety valve, and to

the atmosphere through the choke *m*. The downward movement of the timing-valve piston seats the timing valve *n*; also the air in the reduction safety valve holds the valve *o* to its seat. With these two valves closed, the equalizing-reservoir air is trapped in the spring chamber of the reduction hold-back valve; this makes it possible, as explained farther on, to split the reduction.

104. The flow of brake-pipe air to the chamber above the reduction timing valve piston stops when the equalizing piston seats the discharge valve after the first reduction. The reduction timing valve piston now moves up; this will permit the equalizing-reservoir air in passage *26*, Fig. 40, and the spring chamber of the reduction hold-back valve to unseat the timing valve *n* and escape to the atmosphere through the vent from passage *l*. The equalizing-reservoir pressure in passage *17*, in the first reduction reservoir, and in the space *k* now forces the reduction hold-back valve down, thereby closing port *p* and cutting off the first reduction reservoir from passage *26* and the atmosphere, and connecting this reservoir by way of passage *k* and pipe *17*, and also the equalizing reservoir, to passage *17* and the second reduction reservoir. The equalizing piston again lifts and the second reduction of the train-control application now begins.

The reduction safety valve *o* insures that the second reduction takes place. For example, if the reduction timing valve sticks and does not return to normal position after the brake-pipe exhaust of the first reduction ceases to blow, the reduction safety valve will unseat in a few seconds and vent the pressure in the spring chamber of the reduction hold-back valve to the atmosphere; this valve will then move down and start the second reduction.

The purpose of the valve *q* is to vent any air to the atmosphere that may leak into the spring chamber after the reduction hold-back valve moves down. The first and second reductions will total about 24 pounds from a brake-pipe pressure of 70 pounds.

It is assumed, in the foregoing, that the engineer laps the brake valve as soon as the train control cuts in, otherwise the

equalizing reservoir will be completely vented to the atmosphere. The reason is that pipe *17* is open to the atmosphere in all positions of the brake valve except lap and emergency.

Another reason why the brake valve must be lapped is to allow the pressure in pipe *4* to build up in the spring chamber of the pilot piston. If the brake valve is not lapped, this pressure will escape to the atmosphere at the release pilot valve, which is open in release, running, and holding positions of the brake valve.

105. Summary.—The following summarizes briefly a train-control application: When the magnet valve is deenergized, the air in the blow-down reservoir and in the diaphragm chamber of the timing-valve piston is vented to the atmosphere at the blow-down valve. This causes the timing valve to move and results in the relay piston and slide valve moving to application position; this latter action in turn causes the air in pipe *1*, Fig. 40, and in the spring chamber of the pilot piston to be vented to the stop reservoir and to the atmosphere at the low-speed governor. The venting of air from pipe *4* causes the pilot piston and its slide valve to move to application position; the application piston and its slide valve then move to application position. In this position the slide valve vents the air in the equalizing reservoir to the first reduction reservoir and to the reduction hold-back valve; also, the movement of the slide valve replaces the main-reservoir air above the rotary valve of the brake valve with air from the brake pipe. This latter action prevents the brakes from being released during a train-control application.

The air that discharges at the brake-pipe exhaust port forces the reduction timing valve down and escapes to the atmosphere; also, this air passes to the No. *1* timing reservoir, and to the reduction safety valve, causing it to close. On its way to the reduction safety valve, the air discharges slowly to the atmosphere through a choke. Shortly after the discharge valve seats, thereby completing the first reduction, the reduction hold-back valve opens, and connects the equalizing reservoir and the first reduction reservoir to the second reduction reservoir; this starts the second reduction.

106. Releasing.—It will be remembered that the air in pipe *4*, Fig. 40, was connected to the atmosphere at the low-speed governor valve when the train control cut in. This governor valve does not close until the speed reduces to 20 miles per hour; hence, if the speed is considerably above this amount, the air in pipe *4* will be completely vented. As soon as the governor valve closes, the stop reservoir and pipe *4* will begin to charge with pipe *1* pressure from chamber *E*, through the port in the pilot piston and from chamber *F* through the choke *j*. In about 40 seconds after the governor valve closes, the pressure will have built up sufficiently in pipe *4* and the stop reservoir for the pilot-piston spring to force the pilot-piston back to normal position, Fig. 39. Chamber *B* will now charge with air at main-reservoir pressure from chamber *A* as already described, and the spring will finally return the application piston and slide valve to their normal positions.

The main-reservoir air can now pass from chamber *A* through passage and pipe *6* to chamber *C* between the rotary valves of the brake valve; the brakes can then be released by returning the brake valve to full release position. The gauge hand indicates when main-reservoir pressure is restored to the brake valve.

It will be noted that the reason why the engineer cannot release the brakes during a train-control application is due to the fact that main-reservoir pressure above the rotary valve is replaced by brake-pipe pressure as soon as the train control cuts in. Also, a release is delayed until main-reservoir pressure is restored to the chamber in the brake valve between the rotary valves, and this does not occur until about 40 seconds after the speed has been reduced to 20 miles per hour.

The relay portion of the equipment remains in the position shown in Fig. 40 until the cab indication changes from a low to a high light. The magnet valve then becomes energized, and the relay portion is charged as already explained, thereby causing its parts to move to the positions shown in Fig. 39. The relay slide valve now connects the air in the stop reservoir to the atmosphere and also breaks the connection between pipe *4* and the stop reservoir.

107. Automatic Train-Control Application, Speed Below 20 Miles per Hour.—If the train is running at a speed of or below 20 miles per hour when the cab light changes from high to low, the train-control equipment will operate as already explained, provided, of course, the acknowledging valve is not operated. However, the air in pipe *4*, Fig. 39, will vent only to the stop reservoir, because the low-speed governor valve is closed at speeds below 20 miles an hour. The brake valve should be lapped as soon as the train control cuts in; the pilot piston will then be returned to normal position, as already explained, when pipe *4* and the stop reservoir have charged to the required pressure through the port in the piston and the choke in the relay portion. It requires about 40 seconds after the brake valve is lapped for pipe *4* and the stop reservoir to charge sufficiently to return the pilot piston to normal position. The return of the pilot piston and hence of the application piston will be indicated by the red hand on the large duplex gauge; the brakes can then be released. The relay portion does not return to normal position until the cab light changes from low to high.

108. Manual Suppression at Speeds Above 20 Miles per Hour.—The operation of the train-control equipment is suppressed on a change of cab indication from a high to a low light if the speed is above 20 miles an hour by making a brake-pipe reduction of about 12 pounds. This reduction will prevent the escape of air from the spring chamber of the pilot piston through a portion of pipe *4*, Fig. 39, to the atmosphere at the low-speed governor. At speeds under 20 miles an hour, suppression is accomplished by operating the acknowledging valve, thereby causing the air from the acknowledging reservoir to operate the acknowledging pilot valve, which then charges the stop reservoir from chamber *F*.

Suppression at speeds over 20 miles an hour will be explained first. When the brake valve is placed in service position, the brake-pipe air in pipe *3*, Fig. 39, is connected through a port in the upper rotary valve to pipe *27*. From this pipe the air passes by way of the application slide valve to chamber *H* of the suppression valve; the piston then moves up and closes the valve *h*.

The air in the section of passage *4* between the valve *h* and the spring chamber of the pilot piston is then trapped, therefore the venting of the air in the other portion of passage and pipe *4* through the relay slide valve and passage *9* to the low-speed governor valve will not cause the pilot piston to move. The above portion of pipe *4* is supplied with air through the choke *j* in the relay portion, but the vent to the atmosphere at the reduction suppression valve with the lower valve unseated will prevent any accumulation of pressure in the spring chamber of this valve that would prevent the piston from moving up should the vent at the governor fail to do so. Of course, it is understood that the relay portion operates at the end of the delay time, as already described, when the magnet valve is deenergized, and the air in the section of pipe *4* just mentioned continues to pass to the atmosphere at the low-speed governor valve until the speed reduces to 20 miles per hour.

109. In addition to passing to chamber *H*, Fig. 39, of the reduction suppression valve, the brake-pipe air in pipe *27* passes to the second timing reservoir and through passage *s* and the unseated valve *t* to the atmosphere at the reduction-insuring valve. Also, as soon as the equalizing piston lifts and unseats the discharge valve, the air discharging from the brake pipe passes through passages *18* and *16*, and the slide valve of the application piston to the second timing reservoir and to the atmosphere at the reduction-insuring valve as just explained.

As the brake-pipe reduction continues, the brake-pipe pressure in the spring chamber of the reduction insuring valve will decrease to such an extent that the pressure trapped in pipe *19* and the suppression limiting reservoir will finally force the piston of the reduction-insuring valve upwards, and seat the valve *t*. When this valve seats, the discharge of air from chamber *H* of the reduction suppression valve and the No. *2* timing reservoir ceases, and air from the brake pipe will pass from the spring chamber of the reduction-insuring valve past the valve *u* and passage *s* to chamber *H*. The admission of pressure to this chamber insures that the valve *h* will be held seated, thereby making the suppression permanent, as long as the brake valve

is in lap or service position. If the required reduction of 12 pounds is not made in the brake pipe and in the spring chamber of the reduction-insuring valve the valve *t* will not seat. The air in pipe *27*, in chamber *H* and the No. *2* timing reservoir will then vent to the atmosphere at the reduction-insuring valve, the valve *h* will unseat, and vent the air in the spring chamber of the pilot piston to the atmosphere at the low-speed governor valve. A train-control brake application will now result.

110. If desired, the 12-pound reduction required for a manual suppression can be made in two reductions. If this is done, the brake valve must not be left on lap for more than 2 seconds after the brake-pipe exhaust stops blowing; if so, a train-control brake application will occur owing to the discharge of air from chamber *H*, Fig. 39, and the timing reservoir.

It is not necessary to operate the acknowledging valve when making a manual suppression. However, if the valve is operated, the stop reservoir will begin to charge as explained farther on, and this will permit the brakes to be released more quickly after the speed has reduced to 20 miles an hour. When the low-speed governor valve closes, the pressure will return more quickly to pipe *4*, thereby causing the pilot piston to return to normal position sooner than otherwise.

111. Release After Manual Suppression.—The speedometer indicates when the speed of the train has dropped to 20 miles an hour; this fact, also, will be indicated by the hand on the pipe *4* gauge, which will move up to 70 pounds, thereby showing that the low-speed governor valve has closed and that the stop reservoir is charged. The brakes can now be released if train conditions will permit.

Any attempt to release at a speed above 20 miles an hour will result in the pressure in chamber *H*, Fig. 39, and in pipe *27* being vented to the atmosphere at the upper rotary valve of the brake valve. A train-control application will then occur, because the downward movement of the piston in the reduction suppression valve will unseat the valve *h*, thereby connecting the spring chamber of the pilot piston through pipe *4* to the atmosphere at the low-speed governor valve.

With the brake valve in full release position the brake pipe, pipe *3*, and the spring chamber of the reduction-insuring valve are connected to the main reservoir. The piston in the reduction-insuring valve and the valves *t* and *u* then return to normal position. In this position of valve *t* the air in chamber *H* of the reduction suppression valve, in the timing reservoir No. *2*, and in pipe *27* is connected to the atmosphere at the reduction-insuring valve, also at the same time the air in the above places is vented by way of pipe *27* and the upper rotary valve of the brake valve to the atmosphere. The piston in the reduction suppression valve is now moved down by its spring, thereby permitting the valve *h* to be unseated by its spring. When valve *h* unseats, the air that is trapped in the spring chamber of the pilot piston and in passage *4* between this chamber and valve *h*, as well as the air in the quick-release reservoir is vented to the portion of pipe *4* between valve *h* and the low-speed governor valve. The capacity of the quick-release reservoir is such that the venting of the air in the spring chamber of the pilot piston to the empty portion of pipe *4* will not cause a train-control application. The pressure in the complete pipe and passage *4* will now charge up to train-control pipe pressure through the port in the pilot piston and choke *j* in the relay portion. When the brake valve is moved to running position, air passes from the feed valve to pipe *19*, to chamber *D* of the reduction-insuring valve, and to the suppression-limiting reservoir.

112. Suppression at Speeds Under 20 Miles per Hour.—At speeds under 20 miles an hour, the low-speed governor valve is closed, hence the movement of the relay slide valve to application position when the cab indication changes from high to low will not result in a reduction of pipe *4* pressure. Neither will the air in pipe *4*, Fig. 39, be vented to the stop reservoir, the reason being as follows: On the change of cab indications the engineer moves the handle of the acknowledging valve to acknowledging position. This action vents the air in the acknowledging reservoir to pipe *7*, thence through pipe *20* to the chamber above the acknowledging pilot valve piston. The piston will be depressed, thereby unseating the pilot valve *v* for

about 50 seconds, or while the air in pipe *20* is discharging through the small choke shown. During the interval that the pilot valve is unseated, the train-control pressure in chamber *F* will charge the stop reservoir through passage *14*. The pressure in pipe and passage *4* cannot then unseat the ball check *r* and vent to the stop reservoir because of the approximate equal pressure in each. Therefore, a train-control brake application is prevented.

It will be noted that the acknowledging reservoir is supplied with air from the train-control feed valve. The relay portion will return to normal position when the magnet valve is energized by the cab light changing from low to high. The relay slide valve will then vent the air in the stop reservoir to the atmosphere.

113. Automatic Train Control Application When Low-Speed Limit Is Exceeded With Low Cab Light.—It will be assumed that the engineer has suppressed the operation of the train-control equipment by making the required reduction, and has reduced the speed below 20 miles an hour. If the cab light remains low and the speed slightly exceeds 20 miles an hour, the train control will cut in. With a low cab light, the magnet valve is still deenergized, hence the relay portion is in application position, the position it assumed when the light changed and the stop reservoir is charged to standard pressure Therefore, the air in pipe *4*, Fig. 39, will be vented to the atmosphere through passage *9*, the relay slide valve, and the low-speed governor valve when the speed exceeds the low-speed limit. The ball check prevents the air in the stop reservoir from passing to pipe *4* and the low-speed governor valve. If the brake valve is lapped as soon as the train control cuts in, the brakes can be released, if train conditions permit, in a few seconds, instead of 40 seconds, after the speed has been brought below the low-speed limit. This shorter interval is due to the fact that the low-speed governor valve was only held open slightly for a very short time, hence very little air escaped from pipe *4*.

114. Protection Interlock Portion.—The purpose of the protection interlock portion is to impose a low speed in case

either the main-governor drive or the protection-governor drive should fail. The latter governor opens its valve when the speed reaches 18 miles an hour.

With the main-governor drive disabled, the protection governor, when the above speed is reached, will open its valve *33'*, Fig. 39, and vent the air in pipe *33* to the atmosphere. The interlock piston and slide valve then operate and connect pipe *4* through passage *3* and the protection interlock valve, that, with the drive disabled, is open to the atmosphere. Thus, the train control will cut in at speeds above 18 miles per hour with the main-governor drive disabled.

Should the protection-governor drive fail, the valve *33'* will seat and valve *33''* will unseat; pipe *1* will be connected to pipe *33*; the protection-interlock portion then remains in normal position. Should the speed now exceed 20 miles an hour, pipe *4* will be connected through pipe *9* and the low-speed governor valve to the atmosphere. Thus, under the foregoing condition, the train control will cut in should the speed exceed 20 miles an hour.

115. Relay Brake-Pipe Vent Valve and Maintaining Valve. The purpose of the relay brake-pipe vent valve, Fig. 39, is to vent brake-pipe air to the atmosphere when the brake valve is moved to emergency position. The purpose of the maintaining valve is to permit main-reservoir air to pass to the application cylinder of the distributing valve during an emergency application and thereby give maximum braking power on the locomotive.

With the brake valve in emergency position, the air in chamber *C* between the rotary valves passes under and forces the vent-valve piston and hence the vent valve upwards, thereby permitting brake-pipe air to vent to the atmosphere. At the same time the air from between the rotary valves passes to the right-hand side of the large piston in the maintaining valve, forces it to the left, and permits main-reservoir air to pass by way of the slide valve to the middle pipe on the left, here shown broken, that connects to the application-cylinder pipe of the distributing valve.

GENERAL RAILWAY SIGNAL COMPANY'S PNEUMATIC EQUIPMENT

EQUIPMENT FOR AUTOMATIC STOP

116. Brake-Applying Apparatus.—The brake-applying apparatus, Fig. 41, comprises a magnet valve, and an actuator

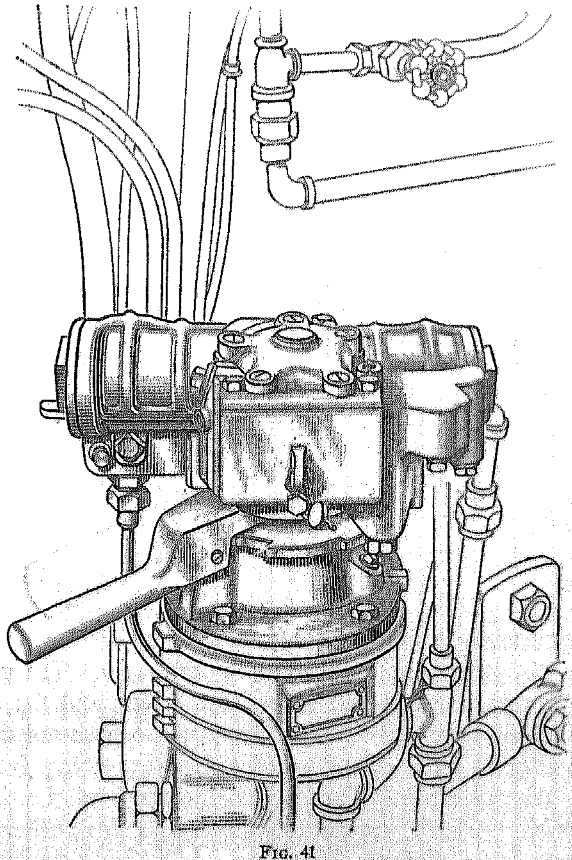


FIG. 41

valve on the brake valve. The brake valve used is of either the H6 or the G6 type with the required modifications to permit of the application and operation of the actuator.

The purpose of the actuator mechanism is to disconnect the brake-valve handle from the rotary valve and rotate this latter valve to service position when the train control cuts in. This action prevents the handle of the brake valve from being used to stop the movement of the rotary valve when the train control operates. Under normal conditions the brake-valve handle can be used to operate the rotary valve without interference from the actuator mechanism.

117. In Fig. 42 are shown the parts of the actuator mechanism that is placed on the brake valve. The handle *a* and the circular portion *b* are cast in one piece. The driver *c*

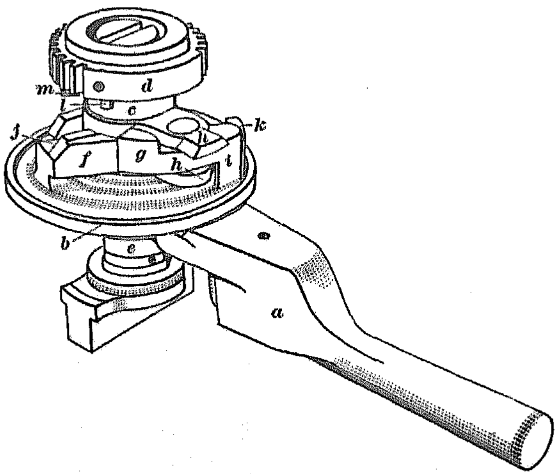


FIG. 42

projects through a circular opening in the part *b*. The gear *d* is free to turn on the upper end of the driver, and the upper portion of the rotary valve key *e* fits into a square opening in the lower end of the driver. The driver has a lug *f* and a latch *g*, the latter being pinned to the wings *h* of the driver. The end *i* of the latch is pressed outwards by a small coil spring, not shown. The gear *d* is here shown in a higher position on the driver than it usually occupies.

With the parts in the position shown, it is apparent that a movement of the handle in either direction will rotate the driver

and the rotary valve key *e*. Thus, if the handle is moved in one direction, its lug *j* will engage the lug *f* of the driver; if moved in the other direction the lug *k* on the handle will engage the end *i* of the latch.

However, when the gear *d* is rotated by a rack on the actuator pistons, the pin *l* will engage the left end of the latch *g* and will carry this end outwards, the other end *i* moving inwards and away from the lug *k* on the handle. The lug *m* on the gear next engages the lug *f* on the driver and turns it and the rotary-valve key; the handle does not move, owing to the end of the latch

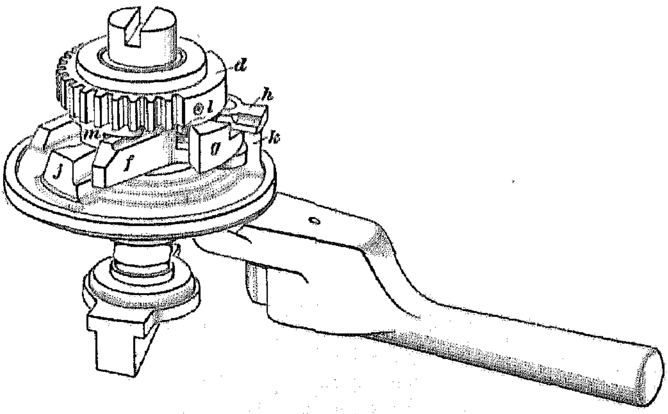


FIG. 43

being out of contact with the lug *k*. The handle is now disconnected from the driver and the rotary valve as shown in Fig. 43.

To latch up the handle with the rotary valve again, the pin *l* in the gear *d* must be turned away from the end of the latch; this is done, as explained later, by admitting air to the actuator cylinder. Next, the handle is rotated slightly beyond service position until the end *i*, Fig. 42, of the latch is forced outwards by its spring in front of the lug *k* on the handle. Then, when the handle is moved toward release position, the driver and the rotary-valve key will turn the rotary valve to release position. The disconnecting of the brake-valve handle from the rotary valve is not confined to road conditions. With the engine in the roundhouse, the air will finally leak out of the

air-brake system and the actuator will usually go to application position. Then, in addition to starting the compressor, the headlight generator must also be started before the handle of the brake valve can be latched up with the rotary valve.

118. Operation.—With the magnet valve, Fig. 44, energized, air passes from the main reservoir through the strainer, thence by the lower poppet valve *a*, now held open by the upper poppet valve *b*, thence through the pipe shown to the large end of the actuator cylinder. The valve *b* now prevents the escape of air through the exhaust passage *e*. The piston *c* is then forced to the position shown. Air pressure is always present in the right-hand, or small, end of the cylinder through a port in the under side of the brake-valve cap.

When the magnet is deenergized by the failure of the engineer to acknowledge, the upper poppet valve *b* is unseated and opens the port *e*; the lower valve *a* is seated by its spring. The air in the large end of the actuator cylinder then escapes to the atmosphere through the port *e*. A part of the air also passes to the whistle and causes it to blow. The rack in the actuator cylinder is then forced to the left by the air pressure in the small end and the brake valve operates as already described. After the train has stopped, the engineer descends to the ground and operates the reset contactor as already explained; this energizes the magnet valve and returns the actuator to normal position. Then, by latching up the handle of the brake valve with the rotary valve, the brakes can be released.

119. Double Heading.—When the double-heading cock is closed, the cock in the pipe between the magnet valve and the actuator cylinder is closed at the same time. This cuts off the magnet valve from the actuator cylinder and keeps the left end of the cylinder charged, thereby preventing the train control from operating on the second engine.

With the Union Switch and Signal Company's systems, the double-heading cock, when closed, prevents the operation of the equipment because the connection between the timing valve and the automatic application valve by the way of pipe 10, Fig. 31, is broken. The magnet valve and the timing valve will operate

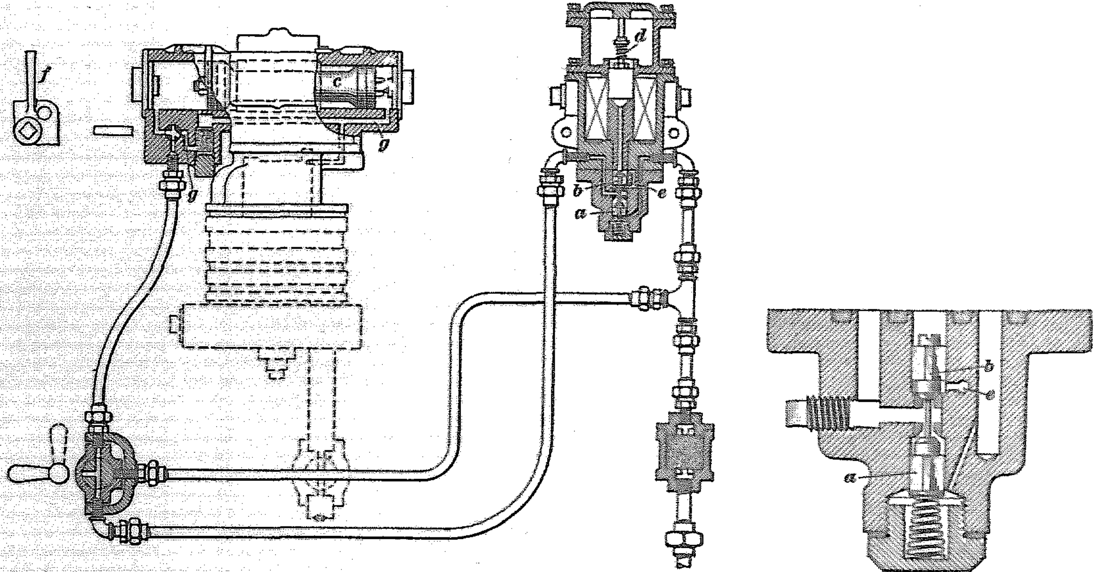


FIG. 44

as usual but no reduction in pressure will occur in the spring chamber of the application valve.

120. Cutting Out.—Should the train-control system get out of order, the magnet valve will be deenergized and the actuator will move to application position, thereby disconnecting the brake-valve handle from the rotary valve. The position of the actuator is indicated by the arrow indicator, Fig. 41; this indicator has a gear that meshes with and is rotated by the gear *d*, Fig. 42. The actuator is in application position if the arrow indicator points away from the actuator cylinder, and is in release position when the indicator points toward the cylinder.

If the actuator does not move to release position when the reset contactor is operated, the seal should be broken and the handle *f*, Fig. 44, of the cut-out cock should be turned vertical or to the cut-out position. In this position, air at main-reservoir pressure is admitted directly to the large end of the cylinder through passage *g*, and the actuator will be moved to release position. The seal passes through a locking pin in the handle of the cut-out cock.